

THE
ONTARIO WATER RESOURCES
COMMISSION

BASIC COURSE

FOR

- WATER WORKS OPERATORS

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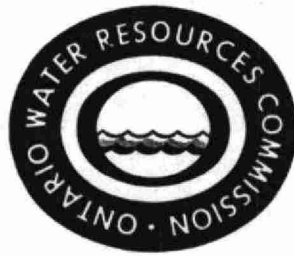
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October 21st - 25th, 1968

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ONTARIO WATER RESOURCES COMMISSION

BASIC WATER WORKS OPERATORS' COURSE

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COAGULATION, FLOCCULATION AND SEDIMENTATION - I

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INTRODUCTION

No attempt is made here to exhaust this subject, impossible in a single lecture, the sole purpose being to present general principles, basic information and some practical guidelines.

Most well waters are sufficiently clear that they need no further treatment and, therefore, we will dispense with any discussion of them.

Our sole concern is those waters derived from lakes, rivers, canals, ponds etc. which are classed as "surface waters". In rare cases, such as at Vancouver and Halifax, the waters are sufficiently clear that they need no treatments of the type indicated by the title of this lecture, but these waters are the exception rather than the rule.

Most surface waters are turbid, which means "having a cloudy appearance", and they do require to be filtered to meet the requirements of a discerning public.

The turbidity, or cloudiness, in a surface water is generally due to a combination of substances suspended in the water and may include mud, clay, silt, organic matter, algae and bacteria.

SOLUTION VS SUSPENSION

It is important to realize that these substances are merely suspended in water and are not by any means in true solution. To understand this fine distinction common table salt can be dissolved in water and it is then in true solution and cannot be settled or filtered out. On the

other hand, substances of the nature of ordinary baking flour, clay, and carbon black cannot be made to dissolve in water but can be stirred into water as a suspension and these substances can be settled and filtered out of the water.

FILTRATION - ONLY A PARTIAL CURE

When we find mud, clay, silt, algae etc. suspended in a raw water one of our first concerns is to remove such substances by means of filtration. In the early days the slow sand filters would remove these substances quite well if the initial concentration of turbidity substances in the raw water was quite low. Slow sand filters had the disadvantage of not being able to handle waters of high turbidity, were very high in capital cost per gallons of water produced, and required a high manual labour maintenance cost, therefore, they were replaced by the Rapid Sand Filter and it is this filter that will be our only consideration here.

When a novice enters the water works industry he often falls into the erroneous belief that rapid sand filters, alone, will remove all suspended matter from water without any assistance from any other type of operation -- nothing could be farther from the truth. Rapid sand filters require maximum assistance from the processes known as coagulation, flocculation and sedimentation. No filter can be any better than the preparation given to the water prior to filtration.

The whole concept of water passing through the sand in the filter is very similar to a stream of air passing through an ordinary wire window screen. If the stream of air contains ordinary fog there will be just as much fog coming out of the screen as had entered it. Similarly, if the water entering the sand bed contains uncoagulated turbidity there will be almost as much turbidity coming through the sand bed as has entered it.

However, in the case of the fog in a stream of air passing through a wire screen, if we first chill the air to such a low temperature that the fog particles condense into snow flakes we then find that the snow flakes are sufficiently large that they are readily retained by the wire screen and only clear air passes through the screen. Similarly, if we can cause the finely divided suspension of mud, clay, silt, etc. in the water to become collected together into much larger particles these larger particles can be retained by the sand and only clear water will pass through.

Obviously, if there are too many snow flakes in the stream of air the wire screen will plug so rapidly that not even air will pass through and, similarly, if there are too many large particles of coagulated turbidity entering a filter, it will also plug far too rapidly to the extent that even water will not pass through. This dilemma is solved by removing a high proportion of these particles by sedimentation (settling) prior to filtration.

SEDIMENTATION - ONLY A PARTIAL CURE

One is often asked why all water works are not equipped with reservoirs for the sole purpose of permitting all suspended substances to be settled out of the water and if this were properly done we could dispense with the necessity of filters. The answers are that natural settling is generally so slow that any such reservoirs would require to be of enormous size, posing a capital expenditure problem and a site location problem, plus also the fact that some of the suspended substances, such as some of the algae and some of the clays, will not settle out.

BASIC PRINCIPLES OF COAGULATION AND FLOCCULATION

Thus, there is the real necessity to cause the finely divided turbidity substances in the raw water to collect together into larger clumps in a fairly short time so that some of these larger particles can be settled out and the remainder retained by a filter. The collecting together of the finely divided particles into larger clumps in a fairly short time so that some of these larger particles can be settled out and the remainder retained by a filter. The collecting together of the finely divided particles into larger clumps is called coagulation and flocculation. In water works practice it is accomplished by the use of certain chemicals, called coagulants, which, when added to the raw water under certain conditions, will produce certain effects.

Let us take the most commonly used coagulant, aluminum sulphate (generally called alum), and add it to a turbid (muddy) water and note what happens. First we should realize that mud, clay, silt and other particulate matter generally has an electrical charge on each particle and generally this electrical charge is negative. Since like charges repel we then realize that the water contains billions of charged particles all trying to repel each other, no wonder then that settling will not take place, or if it does it may take weeks or months. Obviously, we must either get rid of these electrical charges or at least neutralize them.

So we add some alum (aluminum sulphate), which happens to be an acid salt. Within the first few seconds the alum reacts with certain naturally occurring minerals of an alkaline nature in the water and we will take as our example calcium bicarbonate and then the following takes place:

The aluminum sulphate is broken up (dissociates), the sulphate fraction teaming up with the calcium in the calcium bicarbonate resulting in the formation of calcium sulphate which stays in solution. The aluminum from the aluminum sulphate is thrown out of solution as aluminum hydroxide and this substance is virtually insoluble and it in turn becomes a suspended particle.

A chemist would write this reaction in this manner:

$$\text{Al}_2(\text{SO}_4)_3 \cdot y \text{H}_2\text{O} + 3 \text{Ca}(\text{HCO}_3)_2 = 3\text{CaSO}_4 + 2 \text{Al}(\text{OH})_3$$

$$+ 6\text{CO}_2 + y \text{H}_2\text{O}.$$

Fortunately, the particles of aluminum hydroxide are positively charged. Thus, within the first few seconds of the addition of the alum we have produced billions of positively charged aluminum hydroxide particles moving about in a turbid water already containing billions of negatively charged particles of mud, clay, silt etc. Positive and negative charges attract each other and thus the positively charged aluminum hydroxide particles rush toward and stick to the negatively charged particles of mud, etc. The electrical charges are of course neutralized, but of practical value to us is that the particles of turbidity stick to and are enmeshed in the particles of aluminum hydroxide. This all takes place in the first few seconds that the alum is in the water and this is essentially the entire act of coagulation.

Under the microscope in the first few seconds of alum addition we no longer have a uniformly dispersed "fog" of turbidity, but in this first few seconds the turbidity combining with the aluminum hydroxide particles takes on a granular appearance. After about one or two minutes of stirring the granular appearance is so pronounced that it may be seen without the use of a microscope, but, even so, in most raw waters the particles are still too small to be successfully filtered. We have produced coagulation, but that is only part of the story.

After this first stage we continue stirring at slow rate, the length of stirring time being dependent on the nature of the raw water, and the turbidity particles suspended in it. Generally, the stirring time varies from not less than 15 minutes to not more than 60 minutes. During this period of slow stirring we note that the first formed very small granulations are now growing by the mere fact that more and more of them are gathering together into much larger particles looking very much like snow flakes and we call these particles "floc". This entire act of slow stirring to cause the particles to grow by sticking together is called flocculation. After 15 to 30 minutes of slow stirring the particles are so large that you may observe them with the unaided eye at a distance of ten feet. There are exceptions to this, since in some waters the floc always remains small no matter how long we stir.

Having first coagulated the water, then caused the particles to grow large by continued slow stirring (flocculation) we then can shut off the stirring and immediately note two points of great importance: (1) The water between the particles is quite clear, and (2) The particles of floc containing the emmeshed particles of turbidity is heavier than water and begins to settle out.

Observation (1) tells us that the correct amount of coagulant has been used to gather all the undesirable turbidity into the floc that we have formed, and observation (2) tells us that we can remove all of the floc by settling. Thus, if we now proceed to remove all of this floc by settling alone, or by filtration alone, or by a combination of settling and filtration, we are assured of producing a clear water.

Which method should we use? Only settling, only filtration, or a combination of both? You will find that water treatment plants are generally designed to use a combination of both methods for reasons that we will now discuss.

In the case of settling let us assume that we have been conducting our experiments in a laboratory stirring device. The water in the beakers has been continuously stirred to bring about flocculation, but essentially, it is a static sample in that new water is not constantly flowing in and old water flowing out as in the case of a settling basin in a water plant. Thus, in this laboratory demonstration within seconds of stopping the stirring the water is

absolutely quiescent and 100% complete settling can take place. In the water plant the water is never really quiescent, some motion always taking place and thus, depending on various factors, the efficiency of settling will vary from about 60% to 99%. In any event, settling will not be absolutely complete and, therefore, some unsettled floc will remain to be taken out by the filters to ensure a clear water.

You may well ask: If settling is not 100% perfect, then why not dispense with it entirely and let the filters remove all of the floc? The answer is that where the turbidity is high and thus, there will result a very considerable concentration of floc particles in the water, the filters can remove this floc quite well, but generally, only for a very short time. Thus, we could end up with very short filter runs requiring too frequent backwashing. Also, even if the filters did not plug completely we would start to obtain "floc breakthrough", which means that a proportion of the floc would break up and would pass through the filters as turbidity, quite undesirable.

The normal concept, then, is to add the correct amount of coagulant to bring about rapid coagulation, to continue slow stirring so that the coagulated particles can gather together into a large, rugged floc, having sufficient density that preferably 90% or more of this floc will settle out in the relatively quiescent zone in the settling basins (such settled material to be removed either periodically or continuously by de-sludging devices) thence the partially clarified water passes on to the filters where the remaining lesser percentage of floc is retained.

The normal concept is to conduct coagulation, flocculation, and sedimentation so successfully that most of the floc and its enmeshed turbidity is settled out in the sedimentation basins with the filters left to the job of removing that small percentage of particulate matter not settled out by these processes. This is the normal concept carried out on surface waters, some of which may be difficult to coagulate, in all of which we may expect to find turbidities in excess of 20 parts per million, and often up to 1000 parts per million and, in some instances, as high as 10,000 parts per million.

There are always exceptions to the normal concept, for example, your speaker saw a plant in mid-western U.S.A., where the turbidity was always so high that to bring about rapid coagulation and flocculation they required to use excess lime softening. They had also built such an enormous settling basin that by the time the water arrived at the filters it did not really require filtering. They did filter it, however, obtaining filter runs of some 150 hours. The other extreme is the filter plant on Lake Huron to supply the City of London, Ontario. At this plant the turbidity will rarely rise to 20 ppm and thus the floc and the turbidity will always be so low in concentration that it was possible to design the plant without any facilities for sedimentation. All that will be required is coagulation, the water then going directly to the filters. At times it will not be even necessary to employ a coagulant.

It is not possible to cover all possible variations and exceptions in a short preliminary lecture and the general remarks made here essentially apply to the normal water plants treating a normally turbid water in a filter plant, in which the filters contain as media all Cape May type quartz sand or anthrafilt sand, and sometimes a combination of both.

Coming into more widespread use are the new types of filters, which, instead of being one type of sand of uniform size and density, are generally composed of three to four sand layers in which the various sand layers vary in both size and density. These new filters generally operate at a higher rate than conventional filters, generally produce a clearer water, and particularly are able to handle higher concentrations of floc and enmeshed turbidity. These new filters still require the water to be coagulated, often the flocculation period may be reduced and at times eliminated, and, in some instances, the sedimentation zone may be reduced or eliminated. Since these filters can remove turbidities due to floc in the range of 50 to 100 ppm it is possible to place more filters in operation from an existing sedimentation basin.

From all the foregoing, it can be seen that the acts of coagulation and flocculation are essentially a system designed to change a "fog" of turbidity that the filters cannot filter out into a "snowstorm" of floc and enmeshed turbidity, most of which will settle out in the sedimentation basins and that which remains being readily removed by the filters.

Coagulation, flocculation and sedimentation are then none other than a system of adequately preparing a turbid water for filtration.

We have only mentioned one coagulant: aluminum sulphate, called alum. It is the most widely used coagulant in the water treatment practice throughout the world. It is the cleanest to use. It has the advantage that the floc is virtually colorless and if through some misadventure too much alum is applied and some alum floc does pass through the filters it is less likely to be noticed by the public.

OTHER COAGULANTS

Ferrous Sulphate (FeSO_4) - which instead of producing the previously mentioned aluminum hydroxide floc produces a ferrous hydroxide floc ($\text{Fe}(\text{OH})_2$) and generally by means of lime or chlorine some dissolved oxygen is made to change this floc to ferric hydroxide ($\text{Fe}(\text{OH})_3$). Ferric Sulphate and Ferric Chloride are two useful coagulants which also produce a Ferric Hydroxide floc.

Ferrous Sulphate, ferric sulphate and ferric chloride are often called "iron coagulants" because they are derived from iron as opposed to aluminum sulphate which is derived from aluminum.

The advantages claimed for these iron coagulants are that they tend to operate successfully over a wider pH range and that they produce a denser floc which will settle more quickly.

This may be true in some waters, but your speaker has not seen any evidence to this effect on the water that he is required to treat and, furthermore, in laboratory tests he has noted that the iron coagulants seem to enter into a reaction with any organic matter in the raw water so that even after the water has been coagulated, flocculated, settled and filtered the water still has a brownish tinge. Where coagulation, flocculation, sedimentation and filtration cannot be adequately carried out due to plant and filters running far above rated capacity, there is the danger of particles of reddish-brown ferric hydroxide floc going out in the finished water and this will be far more noticeable to the public than the colorless aluminum hydroxide floc.

This does not destroy the usefulness of the "iron coagulants" where they are and can be successfully employed. In the smaller plants, particularly with no chemist in attendance, aluminum sulphate would seem to be the coagulant of choice.

Sodium Aluminate is often used in smaller water works where there is not sufficient alkalinity in the raw water to react with the alum. On occasions it has been found more economical to employ sodium aluminate in conjunction with alum.

Lime is also used as a coagulant. Generally, lime (as Ca(OH)_2) is first thought of as a softening agent and it is widely employed for this purpose. Its value in coagulation is that when used in the high dosages normal for softening it produces such a dense, voluminous, fast settling floc, that it permits the fairly rapid treating in reasonably sized plants of raw waters always having turbidities in excess of 2,000 parts per million. Its value as a coagulant is enhanced if the raw water contains magnesium salts, since the final floc will then contain the voluminous, gelatinous magnesium hydroxide. There are many water plants in the U.S.A. employing excess lime softening, not particularly because they are so intent on having soft water but because of its value in very rapid coagulation, flocculation and sedimentation. Not only is lime softening of value in clarifying waters of high turbidity, but it is also of value in waters that are heavily contaminated with man-made pollution -- particularly lime softening destroys bacteria and viruses and removes organic matter of the protein type.

JAR TESTS

How does one decide the best coagulant for the raw water to be treated? Having decided the best coagulant, how does one at any time arrive at the correct dosage of that coagulant? The answer to these two important questions is: by means of jar tests.

For the record, a most complete description and discussion of the all important "Jar Tests" is found in the Amercian Water Works Association's "Laboratory Manual, AWWA-M 12". This Laboratory Manual was not written at a level to be understood by only university graduates, rather it was written by a rather experienced group of water works men for the benefit of operators

who have essentially no chemical training and, in fact, are not university trained. By means of this book any normal 15 year old boy could go into a water plant and do a rather good job of turning out a clear and safe water. You should obtain a copy.

From this manual, how do we find the most desirable coagulant to use on a particularly raw water?

We start with a 6-place laboratory stirrer. Under each stirring paddle we place a 1,500 ml beaker. Into each beaker we place, from a graduated cylinder, exactly 1000 ml of a fresh sample of the raw water. We set the stirrer operating between 80 to 100 RPM and then to each beaker add, by means of pipettes, definite amounts of a stock solution of the coagulant so that starting with #1 beaker we have increasing dosages up to beaker #6. A good range to start with would be 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 grains of coagulant per Imperial Gallon. After the last beaker has been dosed we permit high speed stirring to continue for 2 minutes at which time we reduce the stirring slowly to 30 RPM, permitting stirring to continue at this speed for 30 minutes.

We look for the speed of formation of floc, its ruggedness, that is its ability to stand some stirring without being broken up, we note the clarity of the water between the particles and when the stirring is stopped, we note the speed of settling. On becoming more advanced one would also measure the turbidity of the water after 10 minutes settling, and the pH and alkalinity.

The procedure is then repeated on the same day with the same raw water using all the other coagulants mentioned above. In so doing, make notes and from your notes and observations you will be surprised how quickly, on the basis of speed of floc formation, ruggedness of floc, clarity between particles, and speed of settling, not forgetting cost, you can readily select the best coagulant for your raw water.

Once having selected the proper coagulant the particular dosage of that coagulant required on any one day is determined in the same manner, but instead of running a number of jar tests changing from one coagulant to another you run only one jar test on your sole selected coagulant, varying the dosage from beaker to beaker, finally picking the lowest dosage that will give you the desired results: fast forming, large rugged floc, clarity between the particles and fast settling.

There are pitfalls to be encountered in comparing jar tests to plant results. For example, on a particularly turbid water, at 500 ppm turbidity, your jar test might show that 3.0 grains of alum per Imperial Gallon would suffice but at this dosage the water entering on to your filters might still be too turbid. Obviously, you would require to continue to raise the coagulant dosage until you had sufficiently reduced the turbidity coming on to the filters, and you might well end up with a dosage of 6 grains of alum per Imperial Gallon, twice as much as the jar test had indicated. Why this discrepancy in the results? Answer: The laboratory stirring device is highly efficient and you gave a stirring time of 30 minutes. It is obvious that your plant facilities are less efficient and that the stirring time is much shorter.

The stirring time of 30 minutes is very proper for selecting the right coagulant and for other research purposes, but on the daily coagulant dosage: check to make sure that the stirring time in the laboratory stirrer matches plant stirring times. Furthermore, if you consistently require to use coagulant dosages running some 2 to 3 times greater than found in the jar tests, then there is something seriously wrong with your plant in matters of design or plant production capacity and consulting engineers should be called in to suggest corrective measures.

To show the importance of the jar tests: we were able to show that our old under and over baffle flocculation system was inadequate and should be replaced with mechanical flocculators. We were also able to show that while alum was the best all round coagulant for our raw water, it seriously needed help from a coagulant aid and out of many such aids available we were able to select activated silica as best for our operation. We were also able to establish a proper dosage ratio between activated silica and alum and to show that in our raw water the activated silica should be added before the alum. Jar tests are all important.

Stock solutions of coagulants for jar tests can be made by dissolving exactly 14.3 grams of the coagulant in distilled water making up the final volume to 1000 ml in a volumetric flask. Alum solution made this way remains stable for months, but the ferrous and ferric coagulants require to be made daily. A stock solution of this strength is such that 1.0 ml added to a 1000 ml sample of water equals one grain of coagulant per Imperial Gallon. Such stock solutions may be conveniently added to the water sample beakers by means of 0.5 and 1.0 ml pipettes.

All water plants requiring to treat surface waters should possess and use Jar Test equipment. Once this equipment is obtained you can arrange with your District Engineer to have one of his technical personnel school you in its use.

OPERATION IN THE PLANT PROPER

How is coagulation, flocculation and sedimentation accomplished in a properly designed and operated plant? The correct dosage of coagulant is continuously measured out and fed into operation by a suitable type of feed machine, a number of good designs being on the market. The coagulant drops from such a machine into a solution pot into which a generous supply of clean water is constantly applied. The resulting solution is then piped directly to the point of application. Black polyethylene piping is very well suited to this purpose. It is very important that the coagulant solution be rapidly dispersed into the water to be treated, therefore, a good point of application is just ahead of a low lift pump, but preferably into a high speed flash mixer.

At this stage coagulation is in effect, the aluminum hydroxide (or ferric hydroxide) is already out of solution as microscopic flocs and the electrical charges on the particles of turbidity have been neutralized. From the low lift pump or flash mixer the treated water should then enter a chamber in which mechanical flocculation is applied. Mechanical flocculation is arranged so as to cause counter currents in the water so as to increase the number of collisions between floc and turbidity particles. Alternately rising and falling dollies, horizontal type revolving baffles, each set of baffles revolving in opposite direction, is used for this purpose. Stirring time, based on the nature of the coagulant and the raw water and other factors should generally be not less than 30 minutes and generally, need not extend beyond 60 minutes. After this period of flocculation the water then enters the zone of sedimentation.

Sedimentation basins should be designed in such fashion that the water can enter, pass through and leave with a minimum of turbulence, permitting maximum settling to take place. Any piping, channels, ducts etc. taking water away from a settling basin should have the minimum number of turns, sharp angles etc. so that undue turbulence will not break up any remaining floc into smaller particles.

The above then is the general concept relative to coagulation, flocculation and sedimentation. It is a basic concept having general acceptance and value throughout the world and, quite frankly, is about all one needs to know in a first course for water plant operators.

APPENDIXpH

pH is a measure of the alkalinity-acidity reaction of a substance. pH 7 is neutral, above that figure is alkaline and below that figure is acid. In treating a highly turbid water with aluminum sulphate, an acid salt, a reaction takes place between this salt and the bicarbonate in the water resulting in the release of free carbon dioxide to the water. This is corrosive to cast iron mains and results in bitter iron tastes and red water problems. The answer to the problem is pH correction to the range of pH 8.0 to 8.5 by means of Calcium Hydrate (lime) or sodium carbonate (soda).

TABLE OF TURBIDITIES COMPARED WITH A TABLE OF COAGULANT DOSAGES

It has often been hoped that someone would publish a table of turbidities alongside a table of coagulant dosages. This cannot be done since the nature of turbidities and raw waters vary so much. For example, a turbidity of 50 ppm in the Columbia river might well be coagulated with only one third of the dosage required to coagulate a 50 ppm turbidity in the river that your speaker deals with. Also, at the beginning of a flood the turbidity is coarse in nature and a 50 ppm turbidity presents very little of a problem, whereas at the end of a flood a turbidity of 50 ppm will be composed mainly of colloidal clays and may require a considerable increase in coagulant dosage.

ELECTRICAL CONDUCTIVITY

Your speaker has not found much value in the measurement and control of electrical conductivity to bring about good coagulation in the water that he deals with; however, where the raw water is very low in mineral matter and there is considerable organic turbidity to be removed then the control of electrical conductivity is of great importance. The Rand Water Board in South Africa is an important example of coagulation being controlled by electrical conductivity.

ACID ADDITION

In highly coloured alkaline waters, low or absent in turbidity, and where it is necessary to coagulate out the colour by means of a "colour floc" it is often necessary to lower the pH of the water by means of sulphuric acid to bring the pH down to the level that alum will work best. Some highly coloured waters are naturally slightly acid and thus no acid need be added and one proceeds to coagulate out the colour by means of alum alone. In both cases, prior to sending the water into distribution the pH should be corrected to the alkaline side by means of lime or soda so as to minimize corrosion.

PHOSPHATES

Most natural surface waters do not generally seem to contain substances that seriously hinder coagulation. Where surface waters have become polluted by domestic and industrial wastes it has been found in the U.S.A. and Canada that phosphate incorporated into detergent mixtures do seriously hinder normal coagulation and coagulation by lime softening. We were able to successfully overcome this problem by the proper use of activated silica.

TEMPERATURE

The colder the water the slower the coagulant is to react. This defect is naturally offset to a great extent by the fact that the water plant is generally operating at a slower rate in cold water periods and, therefore, there is more time for the coagulation, flocculation and sedimentation to be brought to a successful conclusion.

UPFLOW UNITS

Upflow Units are more properly called "solids contact basins". We have previously discussed coagulation, flocculation and sedimentation in what has been described as "conventional plant", which generally implies horizontal flow of water in large oblong shaped concrete tanks.

In upflow units, as the name implies, the water flows upward through fairly well defined zones of operation. In the first or lowest zone, the coagulant is added, coagulation brought about, generally in the presence of some recirculated sludge, the water then passes into essentially a flocculation zone where the floc particles are permitted to grow to such a weight and size that they are able to settle faster than the rising water, thus the fast settling floc forms what is called a "floc blanket". Excess floc may be drawn off continuously or intermittently. In the third zone the almost clear water is essentially "squeezed out" of the floc blanket whence it passes into an overflow weir and then on to the filters.

These devices are excellent where excess lime softening is used, since the heavy floc gives sufficient weight to the floc blanket to prevent it from coming over to the filters which would overload them. These devices are also good in simple coagulation not employing lime softening where the turbidity and mineral content of the raw water is fairly constant and also where plant flow rates are fairly constant. Practically all of these devices require the use of a coagulant aid. On flashy streams, having variable turbidities and with highly variable plant flow rates we do know that operators have had a miserable time in either producing a floc blanket and, if they did, preventing it from rising over the top and thence to the filters. We have heard of some instances where these devices have required "protection" either ahead of them or after them by means of conventional oblong basins and in one case such a device required such protection before and after. Some states in the U.S.A. do not permit their use. The trouble in the past seems that such devices were often undersold on size so as to remain competitive with conventional plant. When built to proper size they are on a par with normal concrete basins as to cost.

COAGULANT AIDS

A Coagulant Aid is anything that will aid a coagulant and quite often a coagulant requires considerable help. In some waters alum will never produce anything more than a small fragile floc. A Coagulant Aid is required to change such a floc into a denser, larger, faster forming, more rugged and faster settling floc.

It is often necessary to apply activated carbon for taste and odour removal. This substance is one of the most difficult to coagulate, flocculate, settle and filter out and, since it is the blackest substance known, the problem is obvious. The variable nature of raw waters is such that in some alum alone will prevent carbon from passing through the filters, whereas in other raw waters unless a coagulant aid is used most of the carbon will go right through the filters, causing many black water complaints. We have found that activated silica solves the problem for us.

In some waters, particularly in winter, the water is not clear enough to go directly to filters and yet it is sufficiently clear that there are not enough negatively charged particles in the form of turbidity to react with even the smallest concentration of positively charged aluminum hydroxide floc so we need to purposely add some negative charges and we can do this with activated silica. Activated silica is particularly successful in relatively clear cold waters and in any water where activated carbon is being applied.

Other coagulant aids have been used in various types of waters with varying degrees of success running all the way from perfection to absolute failure. Such other coagulant aids may be special clays, lime, recirculated sludge (from the settling tanks), sometimes even activated carbon can act as a coagulant aid; the polyelectrolytes, and this group includes a number of proprietary compounds and substances which may include starches, esters of cellulose, gums, polyacrylamides and polysaccharides. Some of these substances have had spectacular success in the U.S.A. We have tried over 25 of these substances in jar tests and have not found one of them to compare with activated silica which in North America, Africa and Europe continues to be the best all round coagulant aid and generally, the lowest in final cost.

ACTIVATED SILICA

This substance cannot be purchased as such, but must be made at the point of application by means of a controlled partial neutralization of a solution of sodium silicate by means of an acid, acid gas, or acid producing salt.

The acids, acid gases, and acid producing salts that may be used for this purpose are: sulphuric, hydrochloric (muriatic) and phosphoric acids, the acid gases are chlorine, sulphur dioxide, and carbon dioxide (from flue gas) and the acid producing salts are: ammonium sulphate, sodium bicarbonate (widely used in the United Kingdom) sodium bisulphate and there are many others.

Activated silica is generally made up as a 1% solution and may be made continuously in the case of chlorine in a device known as a silicator or may be made by the batch process using either an acid or an acid salt.

There are a number of involved factors that should be taken into consideration when selecting the method of activating silica for use on a particular raw water in a particular water plant. Even though this choice requires considerable study the fact remains that activated silica still remains supreme as the best all round coagulant aid.

TURBIDITY-FILTER RELATIONSHIPS

It is very tempting when discussing coagulation, flocculation and sedimentation to branch into the subject of filtration, but you are to receive an excellent lecture on this subject. One point, however, should be made clear in this lecture: it is not possible to dictate a level of turbidity that should be permitted to enter on to all filter beds. The concentration of turbidity permitted to enter on to a filter bed is dependent on the coarseness or fineness of the sand or anthrafilt, the nature of the raw water, the nature of the floc produced in it, the rate that the filters are running, whether you are applying activated carbon, and so on.

The late N. J. Howard required only to bring the turbidity down to 7 ppm on the Toronto filters, but he was using only alum to remove a clay type turbidity, was applying no carbon and Lake Ontario water is fairly easy to coagulate. At our plant just to remove turbidity we have always had to bring the turbidity on the filters down to at least 3.0 ppm and to successfully remove carbon at the filters we must always bring the turbidity down to less than 1.0 ppm by means of

activated silica and alum. The new types of multi-bed filters made of several layers of various sizes and densities of sands are able to handle turbidities running in the range of 50 to 100 ppm dependent on the rate that the filters are operating.

BACTERIA AND VIRUSES

Up to this point we have only mentioned coagulation, flocculation and sedimentation as procedures to suitably prepare water for filtration. We have not concerned ourselves with disease producing organisms.

Filtration was originally put into practice to make the water appear acceptable to the public. Then the bacteriologists were able to show that filtered water was safer since the filters had removed some or all of the bacteria from the water. Coagulation by chemical means with its attendance procedures was put into use to aid the filters in bacteria removal. These procedures became our primary and sole defence against water-borne disease organisms. Complete success at all times not being attained chlorine was introduced as a secondary safeguard. Chlorination practice was then so greatly improved that to some it became the primary and sole defence against the bacteria with the filters being relegated to their original job of making the water look clear.

More recently, it has been shown that disease producing organisms can become so embedded in sewage particles that chlorine cannot penetrate into these particles to kill the bacteria, thus good filtration is required to remove such particles. Therefore, instead of entering into endless and often pointless arguments as to whether chlorination or filtration is the primary defence against disease producing organisms, the wise water plant operator looks upon chlorination as a most important defence against those organisms that it can reach and kill, whereas coagulation, flocculation, sedimentation and filtration are also an important primary defence against those organisms not dealt with by chlorination. In the properly operated water plant both systems of treatment should at all times be maintained at maximum efficiency for the greater protection of the public.

In conclusion, there are no set golden rules, each raw water has its own peculiarities that show up differently in differing water plants. Only by careful experimentation and observation can you arrive at the proper system of operation for your plant and your raw water.

THE HISTORY AND PUBLIC HEALTH ASPECTS OF WATER TREATMENT

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EARLY HISTORY OF SANITATION

The first of the modern water supplies was built in the City of Paris in 1183 A.D. A lead pipe aqueduct was constructed which brought into the city a water supply amounting to one quart per person per day. In London, in 1500 A.D., the first pumped water supply was constructed with pumps built on London Bridge. These pumps provided sufficient pressure on the mains to use the water for fire fighting purposes.

In the middle ages, the sanitation practice was incredibly bad. In the absence of piped water supplies, the water borne disposal of sewage and waste was impossible; excrement was stored in privies and removed by contractors in the middle of the night to avoid as much inconvenience to the public as possible, thence the derivation of our term "night soil". A ditch was built down the middle of the street which served to carry away wastes of all kinds which could be dumped into it. When the rains fell, the ditches were washed clean; however, during the dry season, flies, animals and bugs attended to the material deposited in the ditches. Around 1200 A.D., a by-law was passed in the City of Paris, prohibiting householders from throwing slops from upstairs windows between dusk and dawn for the safety of the passers-by in the streets. The "black death" which passed through Europe about this time killed over one third of the population. The surprising thing is, however, not that one third died but that two thirds managed to live.

These sanitary or unsanitary conditions seem to us deplorable and intolerable, but, to the people of that day who knew of no connection between sanitation and disease, the conditions were just an unpleasant aspect of city life which had to be put up with. As a matter of fact, not only was there no known connection between sanitation and disease, but practically nothing at all was known about the cause of diseases.

Rome was always plagued with malaria which was attributed to the miasma arising from the swamps in the vicinity of the city. On hot quiet nights, the odour of the swamps entered into the city and into the houses, and people got malaria. The way to combat this disease was obviously to keep the windows shut to keep the odours out, and to fill up the swamps and thus remove the source of the odours. The only thing wrong with this, of course, was that the theory was entirely wrong. The disease was transmitted by mosquitoes which thrived in the swamps but otherwise had nothing to do with the odours.

And so, in the middle ages, when there was no knowledge of water-borne diseases, no precautions were taken for sanitation and this attitude carried on down through history to quite recent times.

EARLY HISTORY OF WATER PURIFICATION

The purification of water actually began in London about 1829, when slow sand filters were constructed to improve the clarity of a water supply. The reason for building these filters was not for health reasons.

Slow sand filters consist of large beds of sand. The water percolates at a very slow rate, about one-tenth of one gallon per square foot per minute. Under these conditions a biological film soon develops on the top of the sand consisting of bacteria and microscopic organisms. This film removes dissolved organic and small particulate matter from the water. These filters were very successful in improving the appearance of waters and many such filters were built in Europe and in the eastern part of North America up to 1915.

The implication of water as a factor in the spread of disease was not known when water treatment began. As a matter of fact, the bacterial cause of disease was not known. The filters constructed in London, in 1829, were to clarify water only. The first scientific demonstration that disease could be linked with water was a cholera epidemic in London in 1854. There were a number of separate water supplies in the City of London and all cases of the disease were confined to the users of one particular supply. This was an interesting fact scientifically, but no action, either in science or engineering, resulted from the observation. About 1885, a scientist demonstrated that slow sand filters had the property of removing bacteria from the water.

In 1892, a cholera epidemic occurred in Germany. Two adjacent towns took water from the same river; one town had slow sand filters with no cases of cholera while the other without filters experienced the epidemic. In this way, the demonstration of the connection between polluted water supplies and disease was very definitely established. The developments which then followed in the period from 1885 to 1900, laid the foundation for modern water bacteriology and the bacteriological examination of water supplies. This also resulted in the development of sanitation and disinfection techniques that have made the two water-borne diseases, typhoid and cholera, practically extinct in this day.

The first chlorine used in water treatment was that provided by chloride of lime which was made by absorbing chlorine in hydrated lime. The chlorine for this purpose was produced by a purely chemical process and was correspondingly very expensive. In 1896, George Fuller of Louisville, Kentucky, first used chloride of lime experimentally. The first use of chlorine was at Middelkerke in Belgium from 1902 to 1921. Its use on a continuous basis was begun in England in 1906. The first use of liquid chlorine was in Niagara Falls, N.Y. in 1912. This chlorine was made by the electrolysis of salt. In 1913, Wallace and Tiernan produced the first commercial equipment to measure, dissolve and apply chlorine to water.

PRESENT DAY PRACTICE

From a brief look at the early history of sanitation, you may conclude that people in the Dark Ages were certainly very ignorant. It is true that we have a good knowledge of bacteriology now, although the science of virology is still in its infancy and we have developed treatment methods which insure the safety of the water supply, at least we think we have. We certainly do not dump wastes of all kinds into the middle of the streets as was the practice in the early cities. We build sewers today and dump the sewage into the nearest stream or lake. Sometimes I wonder how far we have really advanced. It is only during recent times that society has awakened to the fact that it was slowly poisoning itself and literally billions of dollars are being spent in the industrialized countries to combat water pollution. We still have a long way to go.

Public health problems are more subtle and complex today. Trace amounts of exotic chemicals discharged from chemical plants, and radio-active substances which appear in some lakes and streams used for water supply purposes have to be dealt with. Cross-connections in the distribution system, where a non-potable water supplying cooling or process water to an industry, may introduce toxic substances or pathogenic bacteria or viruses into the municipal water supply. These problems are quite real in the 20th. Century. It is up to people like yourselves to become familiar with your individual water supplies and distribution systems to guard against these potential hazards.

DISEASE OUTBREAKS IN THE 20TH CENTURY

The fact that communities have been relatively free of attack for generations does not limit the possibility of a water-borne epidemic. Periodically, over the past few years epidemics have been reported which can be related to contaminated water supplies. For example, in November and December of 1959, the community of Keene, New Hampshire, experienced a typhoid epidemic. The source of the infection was finally traced, after considerable investigation, to the Keene water supply. This community's water supply consisted of an unspoiled mountain watershed and a good slow sand filter treatment plant. All of these factors combined with careful water distribution practices would indicate that the consumer would be receiving a safe quality water. However, overnight the water system turned into a distributor of the organisms of deadly typhoid fever.

A curious combination of circumstances lead to the typhoid infection. A wood cutter, working in the watershed area without authorization, was discovered to be a typhoid carrier. His waste had been washed into the city's water during unusual flooding in October.

The epidemic at its height affected 19 people and was known to have taken the life of at least one. The city officials were suddenly made aware that the city was in the business of producing a product -- the safety of which they had a legal and moral responsibility to guarantee. The Council was faced with the alternatives either of paying \$67,000 in settlement of the claims or allowing these claimants to sue the city. One attorney estimated that the costs of going to court could have risen as high as one-half million dollars.

It is noted that for at least a decade prior to the epidemic local health and water authorities, the city's consulting engineer, and the state Board of Health, had all recommended the installation and continuous operation of chlorination facilities. However, the City Council repeatedly denied the requests. The result was that Keene has now paid several times the cost of installation and operation of chlorination facilities and at the same time not have the value of those facilities. Further, the Water Department suffered a considerable loss of public face.

This example has been included here to point out that there will always be a need for continued responsible supervision at any water treatment plant to ensure that the quality of the water will not be affected and that there will be no return to the water-borne epidemics of another era. The first public health requirement in water works treatment continues to be responsible supervision to assure that proper standards are reached to maintain the quality of the water.

PUBLIC HEALTH AND ITS RELATION TO WATER QUALITY

The World Health Organization defines health as "a state of complete physical, mental and social well being and not merely the absence of disease or infirmity". The second definition which has been presented reads in part "public health is the science and the art of preventing disease, prolonging life and permanent physical health and efficiency through organized community efforts of sanitation and environment.....".

The reduction of typhoid fever and other related diseases of the environment has been attained consistently over many years. However, statistics on the occurrence of typhoid fever almost have vanished from the records. Knowledge and the wide application of measures for the purification of water, the control of stream sanitation, and the pasteurization of milk leave little reason for failure to use them to the full. The greatest danger today results not from the suitability of these protective measures, but rather from a false sense of security brought about by the absence of such outbreaks and the carelessness of the use of these methods. There is a need to continually impress all in charge of sanitary programmes with the knowledge that these dangers do exist, and any break in the protective armour can quickly lead to disaster.

The need for water supplies is now receiving more recognition than at any previous time. This can be attributed to a public awareness that unless this commodity is available, public health suffers, communities cannot develop, and gradual deterioration must be expected. The trend to urbanization in this country adds emphasis to this need.

The emphasis on water supply has for the most part shifted from safety against disease to quantity and quality for all uses. A supply that is not adequate at all times is defective in the eyes of the consumer. Similarly, water that is not free from odour, colour and turbidity, or has an objectionable taste or other physical or chemical constituent does not fit into a good public health environment. Thus, the major emphasis has now switched from the original requirement of the safety of the supply to these other factors.

There is an abundant supply of water in Ontario, but distribution of the water creates problems in many places. Pollution in any one of many forms can destroy the available water to a community. The cost of bringing water long distances is high, but in spite of this, water is essential above all else and as such can well be considered as a priceless commodity. As this country grows more and more emphasis must be given to conservation and distribution of water supplies.

THE IMPORTANCE OF KNOWING YOUR WATER SUPPLY

The job of keeping our drinking water safe has become an increasingly vital and difficult task. It is recognized that the war against pollution is in progress but the battle is only beginning. Municipalities still discharge untreated or partially treated sewage into the streams, and industry aggravates the problem by dumping an ever changing variety of chemical contaminants.

The water works, and particularly those in the larger and more populated areas, are now confronted with problems that were not present a few years ago. If the water treatment works are to function properly, it is essential from a public health standpoint, that their personnel know the sources of contamination that are or may become a danger to the quality of the water in their plant. The amount of close supervision required in operating a plant is materially increased in those areas that known sources of contamination are present.

It should not be assumed that all sewage treatment plants are properly designed, have adequate capacity and are capable of turning out a good effluent on all occasions. Therefore, it is essential that the location of the points of sanitary discharge in the area be known and the efficiency of the sewage treatments determined.

Do not take sewage plant effluents for granted. Find out by frequent raw water sampling if they are a danger to the water works and then, if necessary, take every precaution to combat such contamination, until it is eliminated by the provision of better sewage treatment facilities.

Sources of industrial waste pollution should also be known to the personnel of water works plants. An ever-changing variety of chemical and other waste discharges are reaching water works plants. As a result, it is rare indeed to find a water works in an industrial area which does not have some type of taste control treatment available. Radiological, anionic detergent, pesticide, phenolic and other organic wastes from industrial sources and from land run-off have brought new and perplexing problems that are often difficult to solve. Industries are sometimes located extremely close to water works intakes, thereby increasing the need for careful supervision in the water works plant.

In recent years there have appeared in the press and elsewhere statements relative to the increasing hazards to the quality of water supplies from sanitary, chemical and other contaminants that reach and may pass through water works plants. In particular, the number of new enteric viruses that have been discovered to be present in human wastes and against which the usual chlorination treatment has little effect, has caused some concern. It is recognized that modern water treatment methods can and do prevent contaminated water from affecting a community's health in almost every instance. However, there is a limit to even the efficiency of our purification plants if the contaminants are to continue in an ever-changing variety. It is true that conditions are probably not as bad as pictured, as there has been no evidence of any major recession to the water-borne epidemics of a few years ago. It would be folly not to follow with every interest, the work that is being carried out in this field and be ready to make changes in water treatment, particularly in the field of chlorination.

TRAINING OF WATER WORKS OPERATOR IS ESSENTIAL

A well trained operator is definitely of value if a water works plant is to function properly. However, any conclusion that all uncertified operators are unqualified to operate a treatment plant is unjustified. Many operators through adequate initial instruction from their fellow operators, and by studying the literature, become well qualified to operate their own or similar plants. It is, of course, an advantage if the instruction that he has acquired in this way can be supplemented by schools of training to enable him to have a better knowledge of the field of water plant operation.

The water treatment plant operator is vital to the health of the community as producer of safe, palatable water, and to the safety of the community as the provider of adequate water to fight fires. It is essential, therefore, that he have every opportunity to provide the personal supervision that is required in this field.

It is recognized that a water works operator is and will continue to be the main cog in the provision of a satisfactory water from a public health standpoint. It is essential, therefore, that he have assistance and training to assist him to a better understanding of the complex nature of water treatment. As the industrial era develops more fully, there is now a more urgent demand for more research in individual water utilities. Also, there should be an appreciation of the importance of the work of operators so that in the future better salaries will help to ensure more interest in the field and a desire on the part of operators for more knowledge to operate their plants.

SUMMARY

The major public health requirements in the operation of water treatment have been listed as follows:

- a) Maintain the quality of the water to meet the standards established by public health and water works authorities.
- b) Know the sources of contamination that endangers the operation of water works plant and be ready to meet the condition that is created by such pollution. In particular, do not assume that discharges from sewage treatment plants in the area are satisfactory.

- c) Water works personnel should secure as much training as possible in order to be able to supervise operation to the best of their ability.
- d) Water works personnel should evaluate the capabilities of their plant and carry out regular research so as to operate to its peak efficiency.

OPERATION IN COLD WEATHER

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OPERATION IN COLD WEATHER

It is the intent of this lecture to present some basic principles for the operation of the water system during cold weather. No attempt will be made to discuss the principles of frost penetration, soil density, thermo-conductivity of soil or other phenomenon of this nature. It is hoped, however, that this lecture will present some practical operating procedures that can be followed during cold weather to maintain the continuity of the water services under adverse conditions. The lecture has been divided into two parts:

1. Operation of the Distribution System
2. Operation of Treatment Facilities

OPERATION OF THE DISTRIBUTION SYSTEM

Location Plans

A very basic requirement of any distribution system is a proper location plan of the various valves and hydrants. If the distribution system is laid out over a large area, one plan should be available to such a scale that the entire distribution system can be seen on it. This large overall plan should be broken down in convenient segments so that smaller parts of the distribution system can be readily seen. The smaller plan should have all valves and hydrants located on it and properly tied into suitable, permanent items. In some instances this information may also be recorded on cards and maintained in a card box. Care should be taken to tie in the valves to reasonably permanent marks. I recall of one incident in which a main broke and a particular valve box could not be located. Because of this situation a considerably larger area had to

be isolated to cut off the water to the break. After the break had been repaired, further investigation determined that the hydro pole, which had been used as a tie-in for the valve, had been moved by the local hydro utility. I think it even wise to check the location drawings during the more slack periods of the year. Also a watchful eye should be kept on other utilities who may make changes to the topography, road construction, hydro pole relocation, gas pipeline construction, etc.

Preventative Procedures

How many of you here today have ever thought of the difference in construction costs for a distribution system in our temperate zone here as compared to that in the southern U.S.A. or other warmer countries. In these areas the watermains are covered by only several feet of soil primarily to get them out of the way and below the ground.

In this part of the country, watermains are installed at a depth to which the frost generally will not reach. In the Toronto area, watermains are normally installed with a minimum cover of $5\frac{1}{2}$ to 6 feet. In the Ottawa area the watermains are normally installed to a minimum depth of 7 feet. These, however, are average figures and are somewhat dependent on climatic conditions. Sometimes the frost will penetrate deeper than these minimum depths because of an unusually small snow fall. This lack of snow fall takes away the snow insulation and causes the frost to penetrate considerably deeper than would possibly occur in an average year. Consequently one year may cause numerous waterpipes and services to be frozen, whereas in other years in which the temperature appeared to be about the same, very few watermains and services were frozen.

Extremely cold weather usually results in a higher frequency of broken or ruptured mains. This is caused by additional stresses induced in the pipe.

Sufficient quantities of spare and repair parts should be available including pipe, pipe repair clamps, sleeves and couplings, water service parts, etc.

When ice forms on the street surface after the escape of water from a broken main or service, a supply of sand should be available to scatter over the ice.

Repairs to broken mains must be given top priority and crews conducting this work should be supplemented when required. During emergency periods, trained personnel should be concentrated on the repair of the break and minor repairs and routine duties should be assigned to others where possible.

Needless to say, all work on maintenance equipment should be checked, serviced and winterized prior to the freezing season. Mobile and power equipment should be available for duty under all conditions. During extremely cold weather, it is advisable to store air compressors, portable pumps, generators and other power driven equipment in a heated or otherwise protected enclosure. This ensures quick starting of motors and availability of equipment when required.

Power and air tools should be in good working order and small hand tools and special items such as turn-off or curb cock keys, wrenches, etc., should be on hand in sufficient quantities to supply additional emergency crews. Extra street barricades, red lanterns or other warning devices should be available.

The best protection by far against freezing of mains and services is to install them at a reasonable depth below the normal frost line. It has been found, after a break occurs, that old mains had been installed at too shallow a depth or that street grading operations had subsequently removed some of the cover. As soon as such a condition is discovered, the mains should be scheduled for lowering or replacement. Do not, however, use frozen fill or soil for backfilling after the break has been repaired.

Thawing of Frozen Pipes

Modern pipe thawing facilities are a necessity for every water utility located in a temperate climate. Freezing of mains and services has always been a familiar winter problem and interrupted service has become intolerable today on many counts.

There are many causes of frozen pipes but the two important causes are:

1. The pipes are not buried deeply enough for the climate of the area. All mains and services must be placed below the normal frost line, the depths of which is determined by the local climate. It is usually considered good practice to place the pipe at least one foot below the normal frost line to allow for an especially hard winter.
2. Pipes will freeze in unusually cold weather as a consequence of the lowering of the normal frost line. This lowering of the line is typically accompanied by an epidemic of frozen pipes in a community where such an epidemic has never occurred before.

The old-fashion method to thaw frozen pipe was to dig the frozen earth from the pipe and thaw it either with open flames or steam. This was slow and it was dangerous to both workers and service lines. The commonly accepted electrical method of thawing frozen water pipes is relatively new compared with the fire method. Essentially the method consists of running an electric current through the frozen section of the pipe. Heat so generated starts the melting job and the warmer water from the mains completes it. Surface damage is eliminated and labour costs are negligible when compared to the benefits to the consumer and the community.

Hydrant Maintenance

All fire hydrants should be inspected at least twice a year, in the spring and in the fall. The Fire Underwriters Association advocates for inspections annually. Here are some of the items that might be used to determine the condition of a fire hydrant.

1. Note the external condition of the hydrants such as operating nuts, nozzle caps, chains and condition of paint.
2. With nozzle caps screwed up tight, open hydrant fully. Note if all nozzles are tight in hydrant barrels and whether drains have closed properly. If drains have not closed water will appear around outside of barrels on ground.

3. Close main valve. Remove the nozzle caps and observe the rate of drainage to determine whether any obstructions prevent proper seating of the drain valve. Drain valves on Darling hydrants may be flushed by turning operating nut only three turns which unseats main valve and allows water to flush drain valves. This method of flushing drains in most cases eliminates the necessity for removing the internal parts.
4. When closing hydrants, do not apply extra leverage to operating wrench if main valves fail to close entirely. An obstruction may be under the main valve and further forcing of the hydrant would unnecessarily ruin the valve leathers and valve seats. Open and close valves several times to flush obstructions off seats. By this procedure replacements of valve leathers and repairs to valve seats may be eliminated.
5. After hydrants have drained, the nozzle cap threads should be greased with waterproof graphite grease which will not wash off and prevent caps from sticking.

A record should be kept of those hydrants which do not drain properly. Prestone is used sometimes to keep the hydrant from freezing by pouring the solution into the hydrant barrel.

After the hydrant has been used in cold weather the hydrant should be immediately emptied with a hydrant pump so that the hydrant does not get a chance to freeze. This should be done by either the operating personnel or the fire department. Some understanding should be reached between these two parties; however, the main responsibility still rests with the operating personnel that the necessary work has been carried out on the hydrants.

Another problem that may be hazardous to the distribution system is the improper backfilling of the area around the hydrant barrel. I recall one municipality in the northern part of our province in which clay was largely used to backfill around the hydrant. During the winter months the frost would grab the barrel hydrant and lift it several inches causing the horizontal pipe to shear just at the foot of the elbow. This occurred to approximately six hydrants

during the first cold winter of operation. Two methods were used to alleviate this condition:

1. To excavate the material and replace it with a proper gravel material.
2. To wrap tar paper around a barrel so that the frost would lift the tar paper and the tar paper would slip along the hydrant barrel.

The third method that has been used to some extent is the placing of boxes around the hydrant and filling them with straw.

After a heavy snow fall all hydrants should be located and the snow removed from the immediate area of the hydrant so that should a fire develop there is no difficulty in locating the nearest hydrant.

Elevated Storage Maintenance

Special care should be taken to assure that the elevated water storage does not freeze during a cold winter night. Several ideas have been utilized with success in the elimination of a frozen standpipe or elevated tanks:

1. The installation of the heating cable from the top of the tank. This, however, has disadvantages in that should the heating cable become inoperative the cable is frozen to the ice and the ice pulls the cable down. It is also a problem in maintenance in that the average person will not be willing to climb to the top of this installation to check the cable as to its operation.
2. This method appears more desirable to me and it is the controlling of the pumps in such a manner that the tank is filled during the early hours of the morning when the demand on the system is practically nil. The demand on the system during the day keeps the water level in the tank moving, but during the night hours when the demand is small the level is practically constant and is a danger to frost. This has been achieved through a time clock which initiates the water pump should there be a need for the replenishing of these standpipes.

3. The third item consists of imposing an artificial demand on the system; for example, the continual operation of a two-inch water line discharging into a nearby creek, river, etc. Care should also be taken to assure that the controls initiating a pump start-up are in a warm or heated area and that the waterpipes in the area may not become frozen. Here again a small electric heater or a heating cable may be sufficient to keep the area warm depending on the size in which the equipment is located. Consumers often help the operating personnel by allowing water taps in the houses to run to prevent freezing of the waterpipes within the house.

OPERATION OF TREATMENT FACILITIES

Cold weather problems at any surface water treatment plant results for the most part from unusual climatic conditions or from oversights in the design or installation of new equipment.

Treatment Processes

Another cold weather problem concerns the retardation of chemical reactions. As the water becomes colder it becomes increasingly difficult to form a satisfactory floc with alum. This condition is aggravated by the normal drop in raw water turbidity in the winter. With alum floc formation incomplete, there is always the danger of carrying the coagulant in solution through the filters. Later the floc can slowly form in the pipeline as the temperature rises. A good test is to set a flask of finished water aside each day and observe it over a weeks' time for possible flocculation. Should this occur it would be well to examine the treatment system for opportunities of extending flocculating time or adding flocculators if none are presently used. Often the use of ferric coagulants or coagulant aids during cold weather can help solve coagulation problems. Each plant must conduct its own study to determine the solution for its particular problems. Frazil ice is quite a complex problem and will not be dealt with in great detail here; however, the problem is mentioned at this time with a few solutions offered. There may not be many of you here who have a problem of frazil ice. I understand, however, that some of the larger water treatment plants located on the north side of Lake Erie do occasionally encounter this problem.

Frazil ice is a French-Canadian term for fine needle ice derived from the French word called "cinders." Frazil ice is composed of fine particles which when first formed are colloidal and are not seen in the water in which they are floating. The ice at first possesses little or no buoyancy, but soon grows to a larger size in agglomerated mass like snow clusters which can be seen floating on the surface of the water.

Needle ice will not form when ice is present on the surface of the water, but it constitutes a serious winter hazard to many water supplies until this surface freezing occurs. Needle ice forms when the water is super-cooled and is actually a fraction of the degree below freezing temperature. Under these conditions, it requires only a slight motion of the water to cause this super-cooled water to flash into ice crystals. The motion of the water adjacent to an intake structure can be the trigger that causes the formation of these ice crystals. They can form so rapidly under certain conditions that the intake screens or ports may become completely clogged. There is no simple solution to these problems. Fortunately, however, only minute changes in temperature are needed to eliminate the problem.

In summary, frazil or needle ice forms in agitated waters where the water is super-cooled. If the waters are calm, surface ice will form; however, if the water is turbulent, or agitated by wind action, the ice crystals which would tend to form on the surface are circulated throughout the media.

Frazil ice has posed a problem in two major areas:

1. At water power plants
2. At water works intakes

Three remedies that can be used to some success are the following:

1. Application of heat to area of frazil formation
2. Maintenance of continual flow through intake
3. Mechanical cleaning

Application of Heat

The application of electricity to screens or trash racks has been used successfully. This is the same procedure as the one used to thaw frozen pipes in water distribution systems. A source of 600 amps at a few volts should be adequate to break the adhesion of the ice within a few minutes. Heating cables attached to the intake structures should be sufficient to maintain the structure at or above freezing 32°F. Under such conditions, frazil ice will not adhere to the structure.

A live steamline might be maintained to the intake. This method has been used successfully in the Niagara Peninsula where industrial water supply lines taking water from the river are hampered by frazil ice. The steam bubbled through the intake dissipates sufficient heat to break any adhesion between frazil ice and intake structure.

Since frazil ice usually forms during extreme cold night-time hours, a time when most water works are experiencing their minimum demand, it is conceivable that the low flows through the intake could contribute to the ice accumulation. If a system were designed such that during periods of low demand water from the raw water well could be pumped to waste allowing the intake to flow full at all times, it is quite probable that the higher velocities should prevent the adhesion of ice on the intake ports. This is the remedy that is presently being used with some success at the Dunnville water plant.

The method of backflushing, or surging an intake to attempt erosion of the ice accumulations has been used successfully, but is an extremely slow process.

More often than not, the trouble is removed by natural forces rather than by mechanical means although the mechanical removal might hasten the natural process.

Some design considerations that may be useful to minimize the problem of frazil ice are as follows.

1. The intake crib should be of submerged timber construction. Wood resists the adhesion of frazil ice to a much greater extent than steel and concrete.

2. Backflushing equipment and a waste line should be included. Intakes should be located in areas around relatively calm water. This hastens the formation of surface ice under which it is impossible for frazil ice to form.

At the Dunnville water treatment plant during this past winter, a diver was hired to inspect the intake structure during the time of frazil ice formation. It was discovered by the diver that the ice had agglomerated to several feet around the intake structure. This occurred during the time that the frazil ice was decreasing and because of this it is thought that at times it may extend to many feet around the intake structure. The ice was very soft and could be broken quite easily by the diver.

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WATER BACTERIOLOGY

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Division of Laboratories

One of the most important requirements for good drinking water is freedom from disease organisms. Disease organisms are commonly introduced into water by fresh sewage, soil and human or animal fecal material. When this contamination is from human or animal carriers, the consumption of the polluted water by other humans or animals may result in new cases of the disease. If by some mishap, polluted water is introduced into a public water supply, an explosive and widespread epidemic may occur in the community. Prior to the extensive use of chlorine, epidemic outbreaks of disease were quite common.

Bacteria are a group of microscopic organisms, which are sometimes responsible for serious and often fatal diseases in man and animals. They are widely distributed around the world in such locations as: the air - on dust particles; in water - particularly surface waters; in soil - on decaying plant and animal material and in association with plant roots; in food products, either by natural contamination or by planned introduction, such as certain types of cheeses; in man or animals, either externally on the skin or internally in the mouth, throat and intestinal tract.

STRUCTURE AND SIZE OF BACTERIA

Bacteria may be described as minute, unicellular or filamentous, plant-like organisms, which differ from true plants in that bacteria lack chlorophyll (a green colouring substance) and reproduce by simple division of one cell into two. Some types of bacteria are capable of forming specialized cells or spores which permit the organism to survive highly adverse conditions, such as heating, drying and certain concentrations of chemicals, which would be normally fatal to them.

These organisms are found in various shapes and sizes. Some are round or spherical in shape and are known as coccus forms; others are rod-shaped for which the term bacillus is used; and others are spiral or comma-shaped structures. Certain bacteria have long, slender, thread-like attachments known as flagella which permit them to move about in liquids. Bacterial size is usually measured in microns (1 micron = 1/1000 of a millimeter or approximately 1/25,000 of an inch) and variations in cell sizes may range from 0.2 to 3.5 microns in diameter and from 0.5 to 100 microns in length.

SOURCES OF BACTERIA IN WATER

A discussion of water bacteriology falls naturally into three categories, that of disease organisms in water, that of indicator organisms and finally, that of other types or organisms that cause trouble in water systems, treatment processes, ground and surface waters.

Disease organisms may gain access to a water supply from air, soil, animal discharges, contact with diseased material and from sewage pollution. Whatever the disease organism, it does not occur naturally in water, nor will it exist there for long periods. These microorganisms must therefore be transmitted to water from some outside source. Intestinal organisms, such as those causing typhoid and dysentery, are not the only disease organism occurring periodically in polluted water. Bacteria causing tuberculosis, plague, tetanus and viral disorders such as infectious hepatitis are sometimes present in water in large enough quantities to cause concern. Too often this latter group is completely ignored. Water used in washing wounds may also contain infectious organisms, such as the tetanus bacilli, which could cause a serious infection if it enters a skin wound. In estimating pollution, not only is the presence of sewage to be considered but the possibility that water may contain infectious material from soil and other sources.

In bacteriological determinations for sewage pollution, a group of bacteria that are quantitatively proportional to the amount of sewage present, are used as indicator organisms. These organisms are known as the coliform group of bacteria and are commonly found in the intestine of man and animals and in fecal discharges from these sources. Coliforms were chosen over other

types of intestinal bacteria because they are most closely associated with the disease organisms likely to find access to drinking and bathing waters. Others are less widely used as sewage pollution indicators, although they have the advantage of indicating freshness of pollution, severity and source.

In nature, coliforms inhabit part of the intestine, forming one of the largest groups of organisms normally populating the human and animal digestive system. In polluted water, their density is roughly proportional to the degree of sewage pollution present. Coliforms occur consistently in large numbers in human and animal discharges in comparison to harmful bacteria which occur only periodically in large numbers. Coliform bacteria are easily detected by procedures to be discussed, and are themselves harmless to humans under normal circumstances. By watching for their appearance in water through routine determinations, information on their presence or absence and in turn the presence or absence of sewage pollution can be determined before a dangerous level of pollution occurs.

Apart from coliforms and fecal coliforms, fecal streptococci, clostridia and pseudomonads are also present in human and animal feces in large enough numbers to be of value as indicators of unsafe water. Developments in the understanding of these groups and in their identification methods have allowed more precise information to be deduced from water sample analyses particularly regarding the source and duration of contamination.

Many wonder why disease organisms themselves are not used to indicate unsafe water. The major reason for this is that a wide unrelated group of disease organisms can be found in polluted waters and usually any particular type will be in small numbers making detection difficult, unless excessively large volumes of water are examined. Laboratory procedures to detect these organisms are usually complex and take weeks to complete. Most of these tests give no satisfactory estimate of their numbers. The coliform group of microorganisms has a longer survival time than most types of disease organisms and their presence allows a margin of safety in determining not only present, but past pollution.

The other organisms that should be included in any discussion of water bacteriology are those present in association with high levels of organic or inorganic substances. Sulphur bacteria, iron bacteria and actinomycetes represent some of the types of organisms which cause taste, odour and slime growth problems in wells and water distribution systems. The impairment of esthetic water quality caused by these usually harmless organisms, has brought substantial attention to their objectionable qualities, such that they have been termed nuisance bacteria.

DETECTION OF WATER POLLUTION

The presence of sewage pollution in water can be more readily and reliably detected by bacteriological methods than by chemical tests. Suspended solids, nitrates, biochemical oxygen demand (BOD), and other chemical determinations do not positively identify sewage pollution, but they may help to characterize the nature of a pollutant.

The Most Probable Number Technique method (MPN) of determining quantitatively the numbers of coliforms present in a water sample has been in use for many years. Various dilutions of the sample (usually three) are made and similar amounts of water from each dilution are added to replicate tubes containing media to encourage coliform growth. Each of these tubes contains an inverted vial submerged in the medium. If coliform organisms are present, they ferment the sugar contained in the medium, gas will be released and trapped in the vial. It can then be assumed that coliforms may be present in the sample. Further confirmation is made by transferring a small amount of growth from a presumptive tube to a second tube containing a more selective medium for coliform organisms. Once again the production of gas indicates a positive response. The determination of numbers of coliform organisms is made by recording the proportions of positive and negative tubes for each dilution and consulting a statistical table which gives the probable number of coliforms in the sample.

This method of analysis requires approximately four days before positive results may be claimed. The results are a statistical estimation of the numbers of coliform bacteria present. This test is still found useful for the determination of coliform bacteria present in a sample containing a large amount of suspended material or for comparison of results obtained by another method, such as the membrane filter technique.

The Indicated Number test is used infrequently and is a somewhat simpler version of the MPN test. The results are subject to more variability than the MPN test and are only of limited value.

The Membrane Filter Technique (MF) method of analysis, developed in recent years, gives a more rapid and accurate enumeration of coliform organisms. Selected amounts or dilutions of the sample are filtered by a special apparatus through a membrane filter which restricts the passage of coliform and other bacteria. Following filtration, the membrane is removed from the holder and is placed in a dish on a pad saturated with nutrient medium. The dish and its contents are incubated for 22 hours, until the bacteria, particularly coliforms, have had an opportunity to increase in numbers sufficiently to form colonies. Each colony is considered to have developed from the multiplication of one bacterial cell.

The number of colonies appearing on each membrane filter is multiplied by the dilution factor to obtain a direct count of the coliform bacteria present. This direct count method is considered to be more accurate and reliable than the MPN technique, and results can be available 22 hours after the analysis was started. Larger volumes of water can be readily examined and the tests performed much more quickly than by other methods. The MF procedure for determining coliforms in water is the method routinely used by the OWRC laboratory.

SAMPLING TECHNIQUE

The method of taking a sample of water requires that a number of precautions be taken to insure that the water in the sample bottle represents only the condition of the water being sampled at the time of collection.

1. The bottles used should be 6-oz. sterile bottles obtained from the OWRC laboratory.
2. The sample report forms should be filled out giving the type of sample, the source, the sender's name and address, the date and time collected and other pertinent information. These forms may also be consulted on the reverse side for sampling instructions.
3. The sampler's hands should be thoroughly washed and dried before handling bottles and taking samples.

4. The cellophane or plastic covering, which provides some protection from contamination before the bottle is used, should be removed and discarded.
5. If the water is being taken from a tap, the tap should be opened and the water allowed to run freely for at least two minutes before taking the sample. Avoid splashing.
6. If the water is to be taken from an open tank, a well, stream, lake, or other source which requires the submerging of the bottle, it should be dipped below the surface in a manner which will prevent contamination from the sampler's hands or sampling device. A sampling device should be suspended by a copper wire rather than by rope or other material, and this wire can be flame sterilized.
7. The cap should be removed from the bottle and held with the finger tips to prevent contamination of the cap or lips of the bottle, while it is being filled. The bottle should be filled to the mark indicated on the label to leave an air space at the top of the bottle. The air space allows proper mixing of the contents at the laboratory before analysis.
8. Water samples should be shipped to the laboratory immediately after sampling and should arrive within 24 hours. Refrigeration of samples is desirable during shipping.

INTERPRETATION OF BACTERIOLOGICAL RESULTS

The report received from the OWRC laboratory which gives the results of bacteriological analyses will usually express the results as the number of coliforms present per 100 ml. of sample. This number will likely have been determined by the routine MF procedure for coliform bacteria. If other tests are reported, they will be interpreted separately.

When the total coliform count is zero (0), this means that for that particular sample there were no coliforms in 100 ml. of sample. Water, from which this sample was taken, would be considered suitable for drinking purposes. However, it should be realized that this small sample may have represented hundreds ~~and thousands~~ of gallons of water. The

placement of too much confidence in a small sample is dangerous procedure and should be avoided where possible. The emphasis should be placed on submitting at least the minimum number of samples per month as outlined in the OWRC Water Quality Objectives. When total coliform counts are between one to ten (1-10) per 100 ml. of sample, the water should be considered of doubtful quality. If this result recurs in a number of samples from the same source, the reason for the pollution should be investigated. Water which consistently indicates mild pollution should be treated in some manner to improve quality before being distributed to the consumer.

When total coliform counts are higher than ten coliforms per 100 ml., this indicates the existence of gross pollution. If this situation occurs after treatment, or with water in a distribution system, the reason for pollution should be immediately investigated. Additional samplings, pollution investigations and treatment of the water for consumption should be initiated immediately to insure that poor quality water is eliminated.

The presence of coliforms in a sample of water should always alert one to the possibility that disease organisms might also be present and capable of causing disease. A potable water should contain no disease-producing organisms and therefore no coliform bacteria.

When fecal coliforms or fecal streptococci are found present in any quantity in a drinking water, the water should be considered dangerous and unsafe for human consumption. These groups of bacteria suggest fresh recent pollution. Pseudomonads and Clostridium reported also indicate an unsafe condition because they are disease-producing bacteria. "Plate count" and background counts reported usually represent the overall water quality and the higher the density of these bacteria, the poorer the quality of water. These parameters will be discussed in more detail in a later lecture.

LUBRICATING OILS AND GREASES

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INTRODUCTION

All petroleum products are derived from Crude Oils.

Crude Oils vary chemically according to the predominating type of Hydro-carbons (from 40 to 60%). They are classified as paraffinic, naphthenic, aromatic, and mixed base.

Paraffinic and naphthenic are used for lubricating oils and grease.


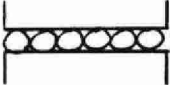

Aromatic are used for asphalt
Mixed basis have all three above

For our discussion we will use only Paraffinic and Naphthenic oils.

LUBRICATION - What is Lubrication?

Lubrication is the ability of a medium to overcome FRICTION.

FRICTION - There are three basic forms of friction:

1.  Sliding Friction - one solid body over another (i.e. two steel plates).
2.  Rolling Friction - (i.e. Ball or Roller Bearings).
3.  Fluid Friction - (Friction in the Fluid Only).

For our discussion we will use the latter (i.e. Fluid Friction).

TERMS USED IN PETROLEUM INDUSTRY

VISCOSITY - is the measure of a fluids "FLOWABILITY".
(e.g. Molasses would be considered to have a high viscosity.
Water would be considered to have a low viscosity).

GRAVITY - is the weight of a substance.

Specific Gravity - is the ratio of weight of a given volume
of material in air, to the weight of an equal volume of dis-
tilled water in air.

API Gravity - is an arbitrarily chosen scale in which the
specific gravity of pure water is taken as 10. Liquids
lighter than water have values less than 10.

VISCOSITY INDEX - is a measure of the rate of change of
viscosity with temperature.

CLOUD POINT - is the temperature at which paraffin wax or
other solidifiable compounds in oil just begin to come out
of suspension.

POUR POINT - lowest temperature at which an oil will flow.

FLASH POINT - is the lowest temperature at which there are
sufficient vapours to ignite.

FIRE POINT - is the lowest temperature at which an oil ignites
and continues to burn for 5 seconds.

BALL BEARING THEORY

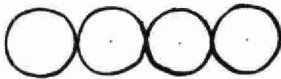
If we represent a lubricating oil by a series of ball bearings, we can then denote the oil weight by the relative ball bearing size.



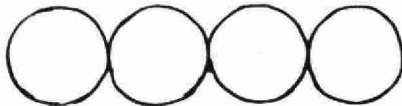
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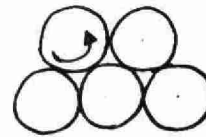
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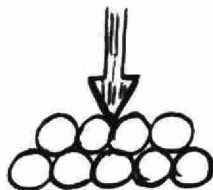
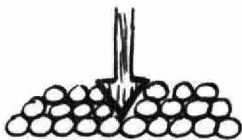
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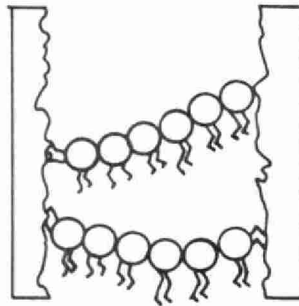
When an equivalent load or force now acts upon ball bearings of different sizes, we find that it is much more difficult to displace the large ball bearings.



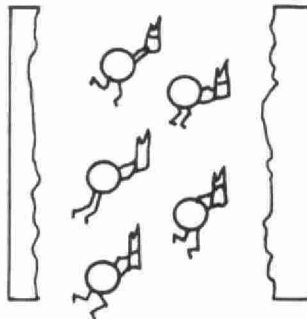
By the same means, a heavy grade oil will more effectively overcome a direct load.

THE FIVE FUNCTIONS OF AN OIL

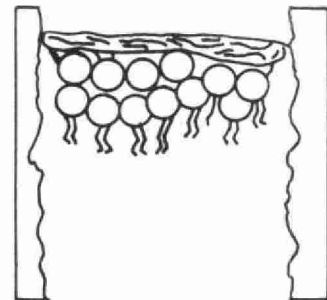
1. TO LUBRICATE



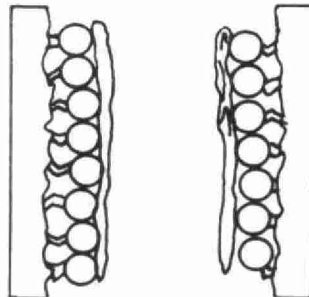
2. TO COOL



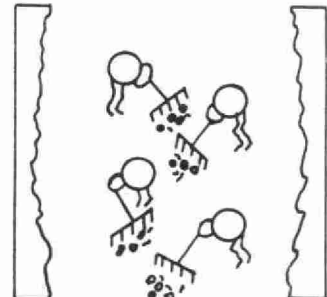
3. TO SEAL



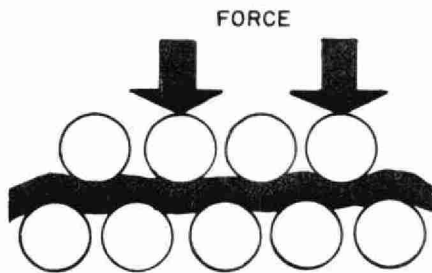
4. TO PROTECT



5. TO CLEAN

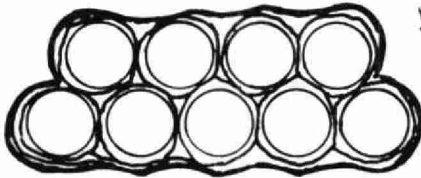


VISUAL INTERPRETATION OF ADDITIVES USING
BALL BEARING THEORY



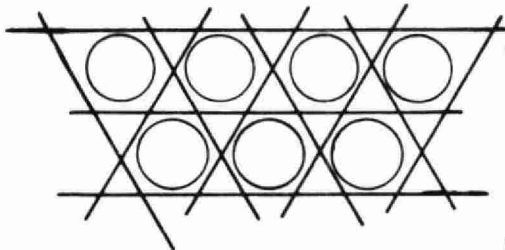
EP ADDITIVE

Could be visualized as a thin piece of plywood.



VI IMPROVER

Could be visualized as rubber band completely surrounding the balls.



ANTI WEAR ADDITIVE

Could be visualized as sticks randomly spaced in bearings.

POUR POINT DEPRESSANT

Could be visualized similar to VI Improver except each ball would be surrounded by lubricating film to stop coagulation.

OXIDATION THEORYBRITAMLUBE 44: FLASH = 405: OXIDATION = 500 Hrs.OXIDATION STARTS AT 160°F: DOUBLES EACH 18°F.

TEMP. °F.	°F. INCREASE	OXIDATION (HOURS)	HOURS LEFT	DAYS LEFT
160	-	1 Hour	500	20
178	18	1 + 1 = 2 Hours	250	10
196	18	2 + 2 = 4	125	5
214	18	4 + 4 = 8	62½	2½
232	18	8 + 8 = 16	31¼	1¼
250	18	16 + 16 = 32	16	-2/3
268	18	32 + 32 = 64	8	1/3
286	18	64 + 64 = 128	4	1/6

OXIDATION THEORYBRITEX R. & O. 44: FLASH = 410°F: OXIDATION = 2000 HRS.OXIDATION STARTS AT 160°F: DOUBLES EACH 18°F.

TEMP. °F.	°F. INCREASE	OXIDATION (HOURS)	HOURS LEFT	DAYS LEFT
160	-	1 Hour	2000	84
178	18	1 + 1 = 2 Hours	1000	42
196	18	2 + 2 = 4 Hours	500	21
214	18	4 + 4 = 8	250	10½
232	18	8 + 8 = 16	125	5+
250	18	16 + 16 = 32	62½	2½
268	18	32 + 32 = 64	31¼	1¼
286	18	64 + 64 = 128	16	-2/3
304	18	128 + 128 = 256	8	1/3
322	18	256 + 256 = 512	4	1/6

WATER FILTRATION

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Water filtration may be described as the process by which water is separated from suspended matter by passage through a porous substance. In practice, this porous material is usually a layer of sand, or in some cases, anthrafil. Records from the year 2000 B.C. state that impure water may be purified by filtration through sand and coarse gravel, and this process has been used in varying ways since that period.

Filtration, as we know it today, began in about 1830 at which time the first of the so-called "slow" sand filters were constructed and put into use in London, England. These units operated at rates of flow of from 2 to 10 USMGD per acre which is equivalent to 0.032 to 0.160 USgpm per sq ft. The "slow" sand filter is rapidly disappearing due primarily to the high labour cost in operating this type of unit, and the land area required. The only one in this particular area still in operation is on Toronto Island.

In operation, the "slow" sand filter consisted of an under-grain system with a gravel bed over it. On top of this was spread the filter sand. The water flowed in on top of the sand and filtered down through it, depositing the turbidity in the upper layers of the sand. Once the rate of flow became too slow for any further operation, the water was shut off, the unit drained, and the top layer of sand removed. The unit was then ready for another run. Periodically, the sand had to be replenished. As you can appreciate, the cost of removing the sand by hand would be considerable.

The "slow" sand filter evolved into the "rapid" sand filter which is in use today. The "rapid" sand filter can either be of the gravity or the pressure type, and in either case, the water passes downward through the bed of sand at rates of flow from 2 to 3 USgpm per sq ft. Since this filter operates at a much higher rate of flow, it is necessary to pretreat the water by coagulation and settling and in this manner, remove the greatest part of the suspended matter prior to the actual filtration process. Unlike the "slow" sand filter, the "rapid" sand filter can be cleaned of the accumulated turbidity by reversing the direction of the flow of the water. This process is commonly referred to as backwashing. In backwashing, the flow of water through the sand expands and scours the bed and carries away, in the water stream, the accumulated solids. There are two types of "rapid" sand filters, the gravity and the pressure types. The internal design of the two units are basically the same; they operate on the same rates of flow. Pressure filters, due to their very nature, are limited to the smaller size since it is not economical to build larger units of this type.

PURPOSE OF FILTRATION

The primary purpose of filtration is to protect the public health. In the earlier days of filtration, this was the only purpose in treating the water. This, however, is no longer true. The tremendous increase in industrialization and urbanization have made it necessary to reduce to an absolute minimum any objectionable odours, tastes and colour as well as providing a finished product of absolute clarity.

In order to meet these requirements, it is necessary to provide a high degree of pretreatment, so that the suspended matter in the water can be gathered together by artificial means into particles of sufficient size, and settled out, or removed by the filtration process. The subject of pretreatment is covered in its own separate lecture.

MECHANICS OF FILTRATION

We know from our own observations and also from laboratory testing, that the filtration process removes almost all kinds of turbidity from the water supply. There are four basic phenomena at work in accomplishing this removal.

Mechanical Straining

The largest particles remain on top of the filter because their physical size will not allow them to pass through the small space between the individual grains of media.

Impingement

Do you remember as a small boy sailing match sticks in the gutter on a rainy day? If you do then you also probably remember that the match sticks had a tendency to float to the side of the stream and promptly adhere to the curbing. Did you ever wonder why it is that when you drive your car on a muddy day in the pouring rain, that the mud that splashes onto your car remains on the car, rather than being washed off by the rain falling from above? The action taking place in either of the above cases is similar to that which takes place when turbid water passes down through the sand grains in a filter. A natural physical phenomena causes the particle to move to the surface of the media and attach itself to it.

Electrolytic Action

Both sand and anthrafilt grains carry an electrical charge as do particles of turbidity which are suspended in the water. These electrical charges alter the physical and chemical makeup of the constituents, in this way, affect the filterability.

Chemical Reactions

There are many organisms present in the top layer of the filter media. These organisms will promote chemical reactions, with incoming turbidity, and other organisms and in this manner affect filtering action.

Construction of a Sand or Anthrafilt Filter

A Gravity Filter is essentially a concrete box. The length and the width will be to suit the configuration of the filters in the building, and the rate of flow which is desired. The depth of the box will be governed by the amount of head, or pressure if you prefer to call it that, required to push the water through the filter at the required rate, and also by the type of underdrain which is used. If you refer to Figure 1 at the back, of the notes, you will note in the cutaway view the principal parts which make up a gravity filter. These are the underdrain system, the gravel subfill, the filter media, the surface washer and the wash troughs. We will discuss each of these in the above order.

Underdrains

The purpose of an underdrain system is to evenly distribute water over the entire area of the filter. The most common type of underdrain is the header, lateral type shown here, and in the latest designs the laterals are thin-walled, stainless steel pipe. Holes are located on the underside of the laterals, and these must be properly sized for the water flows involved in order to ensure that adequate distribution takes place at all times. Since the backwash flow rate of the average filter is 12 to 15 gallons per sq ft per minute and the operating rate only about 3 gallons per sq ft per minute, two very vastly different rates of flow are involved. Since the only head available during the filtration process is the depth of water in the filter, the orifices are normally sized for the filter flow and adequate distribution is ensured at the higher flows encountered in backwash, when ample pressure is available from the backwash pump.

Gravel Subfill

The subfill performs two primary functions. The first is to keep the bed of the filter media, which is extremely fine, from passing out through the holes in the underdrain system. Secondly, to distribute evenly the flow of water which comes from each of the holes in the underdrain system, so that an even flow passes either vertically up or down through the bed of filter media. The depth of gravel which is required in any design of filters is therefore, directly related to the distance between the holes in the underdrain system. A reasonable figure to use for gravel depth is that it should be from 2 to 2 1/2 times the distance between the holes in the underdrain system. Thus if the holes in the underdrain are on 6-inch centres

the gravel depth should be 12 to 15 inches. The bottom or first layer of gravel is extremely coarse. The size of the gravel has to be related to the size of the openings in the underdrains. Normal range is from 1/2" through to 2". While this might seem a very wide range, you must remember that the orifices in the underdrain vary from 1/4 to 3/4 of an inch in diameter. Progressively, finer grades of gravel are spread on top of the course; the minimum depth of a layer is 2" and the final layer of gravel, or "torpedo sand" as it is sometimes called, will support the actual filter media.

Since the function of the gravel is to provide distribution of the water, it is essential that the particles be as near round as possible and completely insoluble. For this reason, the most common material used is silica sea-gravel. Large deposits of this material are found on the Atlantic coast and it is from this area that most of the gravel is imported. Anthracite coal or anthrafil, as it is normally called, is also used as a supporting media. Unlike gravel, it is anything but round, but like gravel it will not pack and will remain open, allowing the water to pass up and down freely through it. Such things as crushed limestone cannot be used as in the first place it will pack down into a solid, impervious layer, (as it does on roadways), and also it will slowly, but surely dissolve in the water.

Filter Media

On top of the bed of gravel is located the actual filter media with a depth of from 27" to 30". The original media used exclusively was sand. This was followed many years later by anthracite coal or anthrafil. Today with the advent of the micro-floc system, we also find garnet as well as other types of sand, which incorporate in the grain structure, such things as carbon, which greatly reduce their weight. Effective size of the filter media will range from 0.15 for garnet to 1.0 ml for the coarser grades of anthrafil. In view of the interest in the Micro-floc system, we will cover this separately in a later section of these notes, and will limit ourselves at this time to discussing single media or dual media filters. These are made up exclusively of sand or anthrafil alone, or the two combined. Normal depth of the filter media will be 27" to 30". The particle size in the filter media is described by a) its effective size, b) uniformity coefficient. The effective size is the sieve size of a media which will have the same hydraulic characteristics as the sample of media, and is the theoretical size of a sieve in millimetres that will pass ten percent of the total weight of the media. The uniformity coefficient equals --

theoretical size of a sieve in millimetres that will pass 60%
theoretical size of a sieve in millimetres that will pass 10%

Filter sand has a bulk density of 100 lb per cu ft and is normally used with an effective size ranging from 0.35 to 0.5 ml and a uniformity coefficient of not more than 1.7.

Anthrafilt is a special type of anthracite hard coal which has been crushed (screened) for size and graded to have a uniform density. Anthrafilt has an average weight of 53 lb to the cu ft and the effective size is in the range of 0.5 to 1.0 ml. The most common grade of filter sand is 0.45 ml; the most common grade of anthrafilt is 0.7 ml. These two filter medias will operate with the same backwash rate.

In order to take advantage of each of these two media, they are now generally used together. They can be readily backwashed together and will always stay separated due to the difference in their backwash characteristics. If the sand grain size is made too fine, then it will begin to mix with the anthrafilt and likewise the anthrafilt grain size is made too coarse, then it will have the same effect. With the coarse anthrafilt on top, the filter will have a large capacity for turbidity while the lower layer of fine sand will provide for maximum particle removal. The combination of the two provide a media that will give greater number of gallons per filter run with a better quality of water.

Directly above the top surface of the filter media is positioned the surface wash equipment. This may be in the form of a fixed grid of pipes with nozzles, or a rotating tubular arm, having small jets all along the trailing side. In some cases a grid may be provided to introduce compressed air into the filter media providing what is commonly called an air wash. Any of the three methods can be used to provide the necessary additional agitation to remove any and all suspended matter from the filter media.

Located above the surface wash equipment, are the wash water troughs. These should be set at a sufficient distance above the bed, to provide a free space between the underside of the trough and the top of the bed equal to 50 percent of the bed depth. This figure of 50 percent is the backwash space normally provided into which the filter media is expanded on backwashing in order to provide for adequate cleaning. The minimum requirement for backwashing space is 30 percent. The depth of the wash trough will vary with their capacity, and therefore, the distance from the top of the wash trough to the top of the bed will vary over a very wide range.

Other necessary appurtenances are the influent, effluent and wash water valves, as well as a valve to control the flow of water to the surface wash equipment. All of these valves are controlled from a console, located indirectly in front of and facing the filter so that all operations involved may be under the direct visual supervision of the operator. Built into the control console are indicating gauges showing such information as loss of head, rate of flow through the filter, and backwash rate of flow. In some older plants, particularly the small ones, individual hand valves are still in use. The large, newer plants incorporate automatic, or semi-automatic, control in which such data as filter flow rate and loss of head is fed into a master control console which automates the valve

operation required in order to automatically backwash a filter and return it to service.

Filter Instrumentation

In order to operate a filter at its optimum capacity and maximum efficiency, it is necessary to have a continuous check on the status of the filter. Such data as turbidity, before and after filtration, loss of head and rate of flow should be continuously indicated and preferably recorded.

Turbidity

The prime function of a filter is to protect public health by removing pathogenic organisms from the water. Most of these organisms are bound up in the coagulated floc particles entering the filter and therefore, it follows that the turbidity of filter effluent is the best indicator of filter performance. Turbidities can be measured in the laboratory by such instruments as the Hellige turbidimeter, and can be monitored on the filters with such indicating and/or recording type instrument as produced by Bowser and by Hach.

Loss of Head

We previously described a filter as a concrete box with an underdrain gravel subfill and filter medium. We failed to mention at that time that the box is filled water. In most filters, the distance from the surface of the water to the centre of the underdrain system is approximately 10 ft. This is the total head or pressure available to push water through the filter. If the filter has just been backwashed, it is in its cleanest form and therefore, offers the least resistance to flow through it. Therefore, it has what is called the smallest or lowest loss of head. In the clean filter the loss of head is 1 to 2 ft, and therefore, the maximum head available during the filter run, is the difference between the total depth and the initial loss, leaving an available head, in most filters, of 8 ft.

As the filter is operated, it removes the turbidity from the water and as the turbidity accumulates in the bed, the resistance to the flow of water increases or in otherwards the head loss through the filter increases. Therefore, the reading of the loss of head is an indication of the "cleanliness" or the "dirtiness" of the filter. Then loss of head gauges become invaluable as one of the means of indicating when the filter needs backwashing. A simple loss of head gauge can be constructed by connecting a clear piece of plastic tubing to the underdrain header, and running the tubing vertically up the side of the filter box so that the open end of the tubing is above the surface of the water in the filter. If the level of the surface water in the filter is then marked on the wall by the tubing, you can at any time measure from this point, down to the liquid level in the tube, and this distance in feet is the loss head. Most modern

loss of head instruments operate on this principle and simply transmit the measurement to the instrument located on the control panel.

Rate of Flow

From our discussion in the last section, I think that you will agree that there is a change in pressure loss through a gravity filter during the period of the run. If there is a variation in the pressure loss across the filter, and the total amount of head available in the filter is constant, therefore, it would normally follow that the rate of flow through the filter would vary with the pressure. This however, does not lead to the best operating results and, as a result, the rate of flow controller was developed to overcome this changing pressure and make the filter operate at a constant rate of flow. The rate of flow controller is nothing more than a valve and a primary measuring device (in most cases a Venturi tube), which when combined will allow the water to discharge from the filter at a constant, but adjustable rate of flow, independent of the change of pressure loss or loss of head as we have called it within the filter proper. The Venturi tube will put out two pressures and the difference in the two pressures will vary with the rate of flow. These two pressures are applied to the controlling diaphragm of a valve in such a way that as the rate of flow through the Venturi decreases, the valve will open and in this manner a constant flow is maintained.

FILTER OPERATION

Pretreatment

While pretreatment is an intrinsic part of every filter plant, and of prime importance to the operation of filters, we will only emphasize its importance in this particular lecture as the pretreatment processes are covered separately and in detail elsewhere.

Filtration Rates

Up until approximately ten years ago, the normal design filter rate for a rapid sand filter, producing potable water, was 2 gallons per minute per sq ft of filter bed area. In the last ten years a tremendous amount of time has been spent investigating filter aids, using dual and multi media. As a result of these efforts, it has now proved quite feasible to increase very markedly operating filter rates. It is not uncommon today to find filter operating at rates of 5 gal per minute per sq ft of filter bed area. The purpose of these newly designed filters is to provide a media in which the particle size is greatest at the top, and through the use of varying types of media gets progressively finer, as we proceed down through the bed to the bottom. Since the voids or spaces between the particles will be larger where the media size is greatest, the voids in the upper portion of the bed are at their maximum and therefore, afford the greatest opportunity for the storage of turbidity. As the water proceeds through the bed, the size of these voids becomes progressively smaller and while at the same time, the storage for the turbidity is

becoming less, the degree of filtration is becoming better. It is not uncommon today to have up to five different layers of material in a filter bed. The multi-layered filter is a part of the micro-floc process. In other types of media two layers are used in which case they are generally sand and anthrafilt and they are commonly known as a dual media filter. The decision, as to which type of process to be used, can only be taken after a thorough study of the treatment process and raw water conditions. We should point out at this point that it is not always possible to increase the rate through any particular filter. Filters are normally designed for specific rates of flow, and such things as the inlet flumes, the underdrain system, rate of flow controllers, and the discharge piping are all sized for this flow. If you were to try and double the rate of flow, it is doubtful if the total head available in the filter would be sufficient to carry this out. In many plants it is quite feasible to have two different rates of flow at different times of year. This is particularly true with waters that are difficult to coagulate. It is often necessary to reduce the rate of flow through the plant during the winter months, in order to compensate for the poor quality of water being fed to the filters, or alternately accept the poorer water quality.

Backwashing

The process of backwashing a filter is the exact opposite of filtration. The water rises vertically up in the filter rather than pass down through it, and the process is to remove turbidity from the filter rather than collect it. Municipal filtration plants always utilize treated water for backwashing. The water is delivered to the filter either from an elevated tower or from a backwash pump, either of which provide adequate pressure and volume in order to carry out backwash process. A normal rate of flow in backwash for conventional filters is 15 gal per minute per sq ft of filter bed area. These figures, however, will vary depending temperature of the water being used to backwash. As the temperature increases, so the backwash rate must be increased proportionally in order to give the same amount of expansion to the filter bed. The backwash water enters through the underdrain header and is distributed evenly over the entire surface of the filter by the orifices of the underdrain system. It rises up through the gravel bed and enters the filter media. The gravel bed further distributes its water so that the distribution is uniform throughout the entire filter. We should mention at this point that its extremely important in the operation of any filter that all valves be opened or closed slowly, since any abrupt change in the rate of flow can disturb the gravel subfill. Therefore, when backwashing it is necessary to open the backwash valve extremely slowly. As this valve is opened, the amount of water rising up through the filter media will gradually increase and as more and more water is forced up through the sand bed, the pressure on the underside of the individual grains of filter media becomes greater. This pressure eventually overcomes the weight of the particle of filter media and the point at which this occurs is known as the point of fluidity. Once the flow

reaches this point, the particle will then begin to rise and the filter bed will begin to expand. The normal expansion of the filter bed is 30 to 50 percent during the backwash period. During our earlier discussion of wash troughs, we mentioned the fact that the distance from the top of the filter media to the underside of the wash trough, was 50 percent of the depth of the media itself, and this is the backwash space and the space into which this filter media will expand during this time. The particles of media do not stay stationary but rather roll around in the bed continuously rising and falling. In the process they rub against each other and the combined action of the water moving past the particle of sand, and the scrubbing action of the particles of sand rubbing against each other physically removes the accumulated turbidity from the filter media grains.

It was found from experience that this procedure does not always remove all of the turbidity from the filter media, and that over the years, there would be an accumulation on the media grains, which would limit their effectiveness as a filter media.

In order to overcome this accumulation on the filter grains, various types of surface wash systems have been installed. All of them incorporate jets which impinge down on the grains of filter media and physically aid in removing the layer of accumulated turbidity. The most common unit in service to day is the Palmer filter bed agitator. This unit is installed directly above the bed and is a self-propelled revolving agitator incorporating high velocity nozzles or jets, which are inclined so that they discharge at an angle down into the bed. The jet of water not only cleans the filter media but also propels the arm, causing the entire assembly to rotate. It is most important that the minimum designed water pressure be provided for these units as without adequate pressure, they are quite ineffective.

In operation, the filter media should be backwashed at the point of fluidity which we referred to before. This flow is about 6 gpm/sq ft/minute. This is the point at which the particles of media are in effect weightless in the filter bed. The Palmer agitator is then turned on and allowed to run for a period of 5 to 7 minutes. The force of the jets of water from the agitator are sufficient, not only to clean the grains of filter media, but also to cause them to move so that the entire bed is gradually turned over and exposed to the jet action. At the end of this period the backwash rate is increased and the agitator turned off. The filter is then backwashed at its normal backwash rate for an additional 3 to 5 minutes, and continued as long as necessary in order to remove all accumulated turbidity. The water is then slowly turned off the media allowed to settle.

Do not be stingy with backwash water! It is most important that the sufficiently high expansion of the filter be used, in order to ensure that the rise rate or velocity of the water rising up in the filters is sufficient to carry the particles of turbidity out of the filter and into the wash trough. While lower rates of flow appear in many cases to do the job, it is false economy, if all the turbidity is not removed.

Operating Problems

The operating problems of a filter can be divided into two categories --

1. mechanical failure of controls and equipment,
2. failure of the filter itself.

An adequate and properly coordinated maintenance program will do much to minimize mechanical failures. Modern day controls and equipment are quite reliable when installed and operated in accordance with the manufacturer's instructions. Regular surveillance and maintenance of such equipment will keep it in good operating condition.

In assessing the reasons for the failure of a filter bed, we must be aware of the troubles which are most likely to occur.

1. Clogging of the filter media due to accumulated turbidity resulting from incomplete removal during the backwash operation.
2. "Cracking" or contraction of the bed which results from too long a filter run, as a result of which the media becomes too dirty and sometimes will pull away from the filter wall, allowing untreated water access to the lowest layers of the bed.
3. Mudballing - formation of tiny balls of accumulated turbidity binding together particles of filter media. As these increase in size, they become heavier than the filter media and gradually sink to the bottom and collect immediately above the upper layer of gravel.
4. The shifting and intermixing of the gravel layers - this problem occurs primarily in the fine gravels located in the top of the supporting bed. It is caused by an even backwashing, rapid change in flow rate, a clog or break in the underdrain system.

The measures which are necessary to overcome any of the above difficulty are largely quite obvious, and in some cases are not necessarily the fault of the operation of the filter itself. Filter clogging is a prime example of this in that it is frequently caused by inadequate pretreatment and methods of providing adequate treatment are discussed on this section of the course. One other point should be mentioned here. In many cases clogging can be overcome by pre-chlorination which will limit bacterial growth in the media.

Cracking or contraction is generally the result of either inadequate backwashing or of overrunning the filters. We mentioned during our discussion of loss of head that it is one of the guides as to when backwash is required. The other is of course turbidity in

the effluent.

We cannot emphasize too strongly the importance of adequate backwashing in every filter operation. The backwash flow rate should be as high as possible without losing filter media. It should be carried on until the filter media is cleaned. We would suggest that samples of sand be taken periodically after the backwashing has been completed. The samples should be taken at 6" increments down through the top 18" of the bed. The samples can be added to clean water and shaken up. From the amount of turbidity still left in the sample, a check can be made of the condition of the media. I should point to you that no media will ever be absolutely clean, regardless of the extent of the backwash.

Reference has been made to the "micro-floc" filter in describing multi-layered system of filter media, and to the fact that grades are such that the coarsest media is at the top of the filter and the finest media at the bottom. The purpose of course is to provide the greatest amount of storage for turbidity within the filter media while, at the same time, providing a fine media which will produce effluent water of the greatest of the best quality. The filter is frequently accompanied by a coagulant control centre, which consists of a small pilot filter which is in continuous operation. A sample stream of the pretreated water is direct to the pilot filter and the turbidity of the effluent is measured. The degree of turbidity in this effluent is used to control the amount of coagulant fed into the main pretreatment, and in this manner, the main plant is controlled so that it produces water of the greatest degree of clarity. In many cases the pretreatment with a micro-floc system does not include sedimentation, but only simple flash mixing followed by flocculation. All the turbidity plus the coagulants are taken out in the filter itself.

Pressure Filters

There is relatively little difference in the design of gravity and pressure filters as far as the internals are concerned. There is one very large difference in their operation, however. Where gravity filter only has a pressure of approximately 8 ft of water on it, the pressure across the bed of a normal pressure filter can be anything up to 60-70 psi. It is therefore, possible to drive the water through these filters under any condition in which the filter might be found.

Since it generally is not feasible to provide very large vessels in which the equivalent of flocculation and sedimentation take place, it becomes quite difficult to provide adequate settling, and then move the water from the effluent of the settling basin into the filter. This normally requires pumping and the pumping process in itself will break up the floc particles and make subsequent filtration difficult. The in-line application of a coagulant such as alum by enlarge is not satisfactory, and lends itself to only a very limited number of waters. The advent of the coagulant aid or poly-

electrolyte as they are commonly called has been a great help in this type of application, as they do lend themselves to in-line application and to the rapid formation of a floc.

Since you cannot see the sand bed during the backwash period, many operators are somewhat reluctant to backwash pressure filters at the rates at which they should be operated. The best procedure is to provide a sample stream which can be examined continuously during backwash, and ensure that the rate of flow is not so great as to cause the filter media to backwash out of the unit. From time to time it is necessary to increase the backwash rate to a point where a small amount of media is being lost in order that you are always aware that the unit is being backwashed at the maximum possible rate. Since all these difficulties can quite adequately be overcome, through the installation of proper controls, pressure filters of either the vertical or the horizontal type can be used to quite good advantage in the small installations, where a cost factor makes gravity filters impractical. The difficulty of providing adequate pretreatment, however, unfortunately limits their application.

Diatomaceous Earth Filters

Diatomaceous earth filters can be best described as a filter in which the filter media is discarded along with the accumulated turbidity. The filters themselves are either of the pressure or the vacuum type and in either case the water is clarified by passing it through the diatomaceous earth. Diatomaceous earth is held on a fine mesh fabric or screen called septum by the pressure of the water passing through it. Diatomaceous earth removes by filtration the turbidity from the water, and accumulates it in the coating or "cake" as it is commonly called. Diatomaceous earth is a natural occurring material composed of the fossilized skeleton remains of microscopic water plants known as diatoms. Each tiny diatom is a very porous structure of almost pure silica and therefore makes an ideal filter media. In the operation of the filter a small amount of the earth is circulated through the filter and accumulated on the septum, building up a thin cake known as a precoat. The raw water is then fed to the filter and mixed with the water is a small amount of additional diatomaceous earth, this portion is known as the body feed. We have a continuous accumulation on the septum of a mixture of turbidity and diatomaceous earth. Since diatomaceous earth is by nature porous, we can control the rate of pressure build up by controlling the amount of body feed. The limit of filtration is governed by the pressure loss across the filters; 30 psi are not uncommon in pressurized systems. When the maximum pressure has been reached, the direction of water flow is reversed and the accumulated diatomaceous earth and turbidity is flushed to the drain. A new precoat is installed on the septum and the filter is ready for a new cycle. Like the pressure filter, this type of system has only proved competitive from a cost standpoint on the small systems.

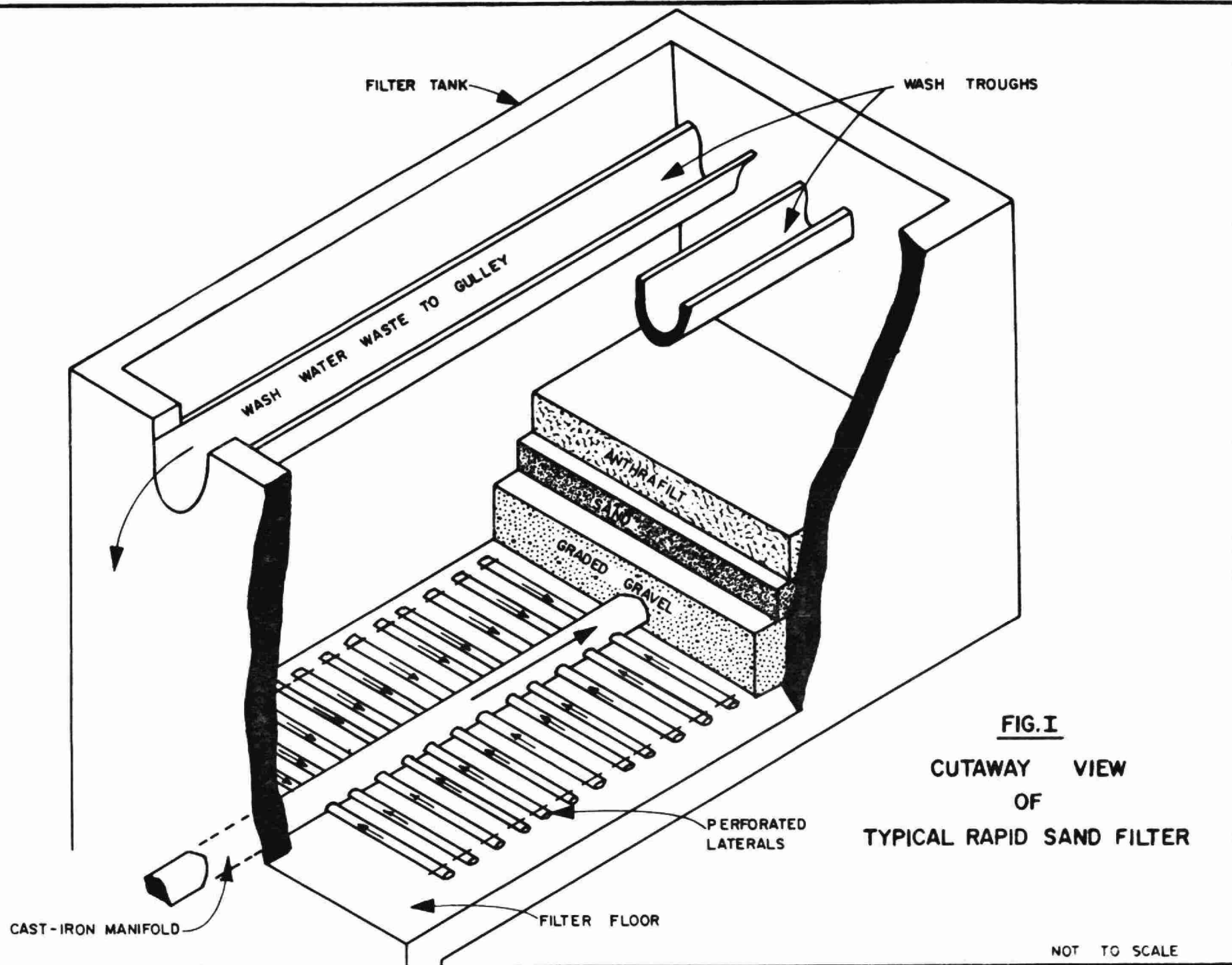


FIG. I
CUTAWAY VIEW
OF
TYPICAL RAPID SAND FILTER

NOT TO SCALE

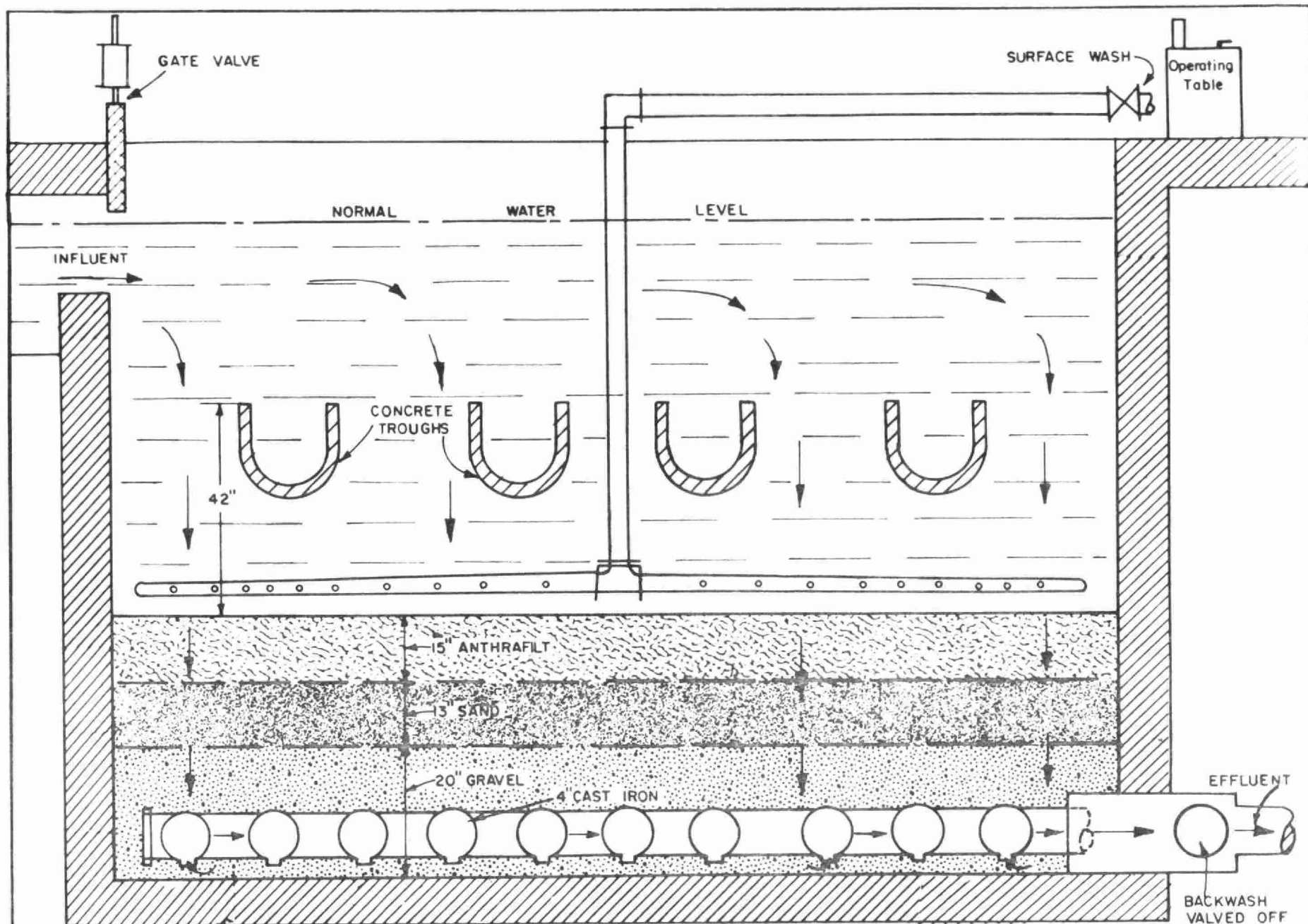


FIG. 2
FILTER IN OPERATION

NOT TO SCALE

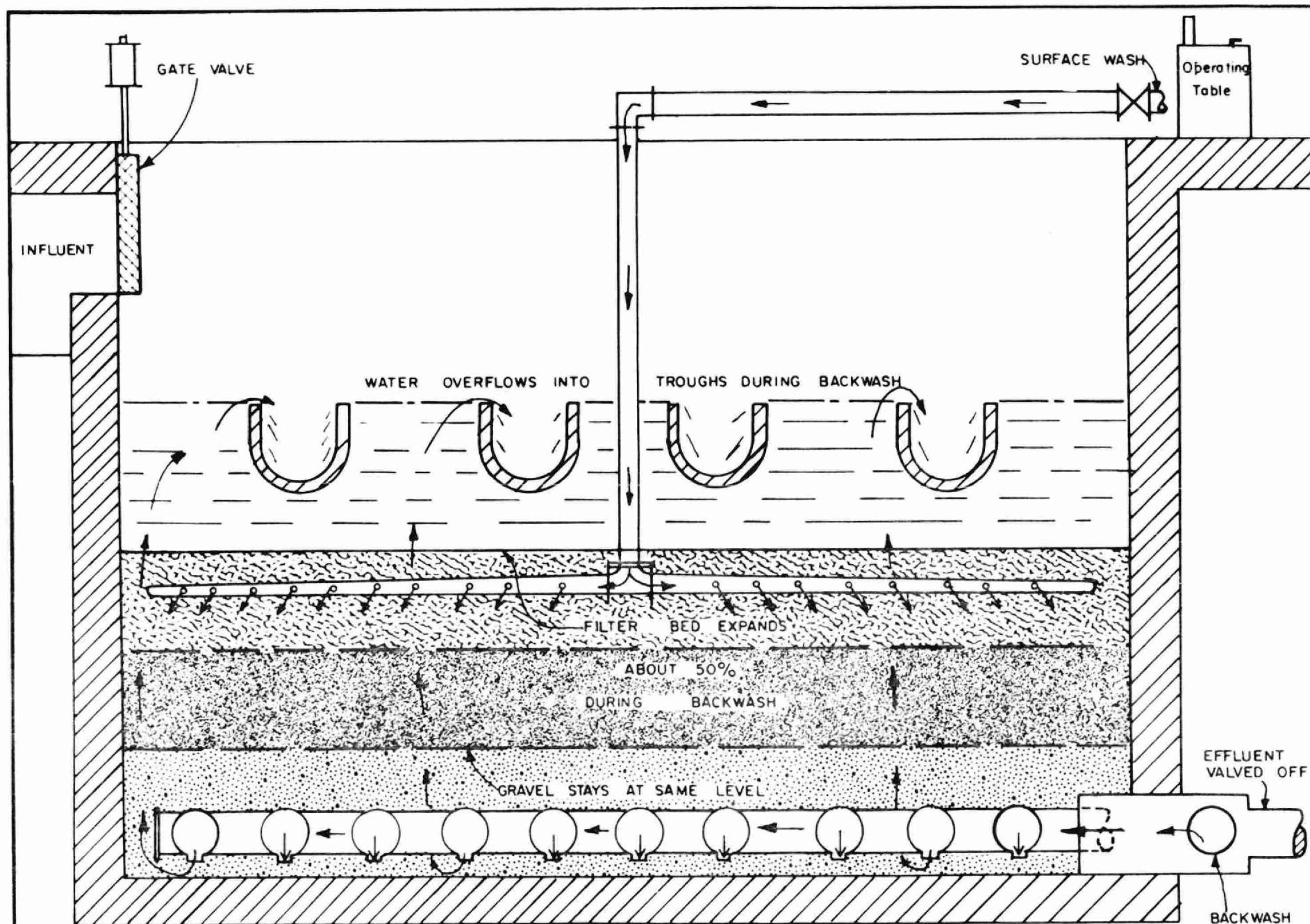


FIG. 3
BACKWASHING A FILTER

NOT TO SCALE

OPERATION IN EMERGENCIES

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INTRODUCTION

For a number of years now the need to prepare for emergencies has been widely publicized with special emphasis on bombings, particularly of the atomic variety. As impressive as the results of man made catastrophes might be, attention must still be paid to the threat of natural disasters, which though perhaps less destructive, are more likely to occur. Not a year goes by in which no part of the country experiences some type of emergency with greater or smaller consequences. No city or town is immune to disaster. Floods, explosions, hurricanes, ice storms, power blackouts, can strike any city or town without warning.

In any emergency there are many parts to be played by many persons. Before launching into the technical details of emergency operation I would like briefly to outline some of the thinking behind emergency procedure and the role played by you the water works operator.

PLANNING

Numerous articles, papers, and conferences have been presented and held regarding the subject of emergencies at water works. The basic theme of all of these, can best be summarized by the Boy Scout motto "Be Prepared".

Every water works, whether operated by a municipality, Public Utilities Commission, institution or a private company, should have a plan to place into immediate action should an emergency come. Many of the problems that may arise can be met by careful thinking and adequate planning before the emergency or disaster strikes. The two basic necessities of a disaster plan should always be borne in mind: knowing what to do and knowing how to do it. A course of action must be planned and personnel trained to carry it out. Without these essentials no disaster plan can be effective and successful.

CONCENTRATION OF AUTHORITY

One of the difficulties encountered in any organization of medium size is that major deviations from ordinary routine usually have to be referred to higher levels of management for

decision. In the event of a disaster, this refinement may not be possible. First because of the time required and second because of probable restriction in communication. It is therefore necessary to establish a clear cut line of authority that is operable on all levels so that the organization can begin to function as quickly as possible following an unexpected interruption in routine operation. Someone should be chosen to head up emergency operations.

It has been found by observation of other successful plans and through direct experience that, once the person of responsibility has been selected, that person must be available at all times for decisions. Headquarters should be established and the person assuming the responsibility on a local level should go immediately to the headquarters and stay there. This way everyone knows where to look for him. The natural reaction of most people in emergencies is to rush about quickly and satisfy their personal curiosity by direct personal observation. Such action greatly reduces the effectiveness of the entire crew. The chief authority should not leave the operational headquarters to observe field conditions through the initial stages, but must base his conclusions on the observations of others who report to him. Only in this way can sufficient balance be maintained to marshal forces to the most pressing needs.

DAMAGES SURVEY

After the establishment of an operational headquarters and determination of the person of authority, the first item of business is to make a survey of the disaster. All available personnel, with the exception of the chief are immediately dispatched to cover individual sectors of the community. This is where you come in. Their instructions are not to stop to make any repairs, to survey the situation quickly, and to bring this information back to headquarters as soon as possible. In this way forces may be dispatched to the more pressing problems first according to a logical sequence of priorities. What may seem to one person to be disastrous in the particular sector may be very much less important by comparison with damage in other sectors. A decision should be made at headquarters and made as soon as possible. The person in authority should dispatch his personnel where they will do the most good, not simply to those problems which are first apparent.

ISOLATION OF DAMAGES

The second step after observation of the degree of damage, is to cut off and isolate the damaged portions of the system before making repairs, so that the maximum uninjured part remains operable and the greatest possible saving of storage reserves can be made. At this point it becomes necessary to establish communications with others. Information must be provided to the Fire Department as to those areas where the availability of water may be curtailed. The health departments, police department and others must be made aware of the situation.

Once the degree and nature of damages has been established the next important steps to be followed are the actual repairs themselves. The aim of your water works system should be to maintain pressure in the distribution system; to make needed repairs promptly; to proceed with emergency chlorination until all danger from contamination is past; and to keep consumers informed throughout all the stages of the disaster.

The following outlines methods of repair and disinfections of systems before or after they have been damaged primarily due to flooding.

However, the methods outlined for disinfection are generally applicable regardless of the cause of disruption or contamination.

CHLORINATION TREATMENT AT THE WATER WORKS

Flood waters entering the system from the water works should be chlorinated at such a rate to give a chlorine residual of about 2 ppm after 15 minutes contact time. Personnel with chlorine testing kits should begin to fan out from the plant to determine the travel of the chlorinated water. The rate of application should then be adjusted to maintain a chlorine residual of between 0.5 and 1.0 ppm in all parts of the distribution system. Any spot that does not clear up within a reasonable period of time should be flushed by opening hydrants. Bacteriological samples should also be taken to prove the effectiveness of the chlorination.

An unpalatable water drives consumers to use other waters which may be unsafe. If heavy chlorination causes objectionable tastes and odours, ammonia in the form of ammonium sulphate or anhydrous ammonia may also be added at the water works to minimize tastes due to chlorine. Concentrations of chlorine in

excess of 1 ppm may kill goldfish. The consumer should be educated to consider the smell and taste of chlorine as a sign of safe water rather than undesirable water.

If the distribution system becomes contaminated during the disaster or following it, the health department officials through the disaster headquarters should issue a warning that all water used for drinking and cooking purposes should be boiled until the system has been found bacteriologically safe.

SHUT DOWN PROCEDURES

If it becomes necessary to shut down the water works, all consumers should be warned in advance. The people should be asked to store water but not to fill bathtubs in order to avoid a sudden demand on the system which may dangerously deplete pressures and reduce fire flows:

(1) Well Supplies

When a flood threatens to cover a well, the unit should be run continuously to fill all storage reservoirs. The motor shaft should then be uncoupled; the bolt holding the motor frame to the bedpipe loosened; and the motor blocked high enough in the air to be out of reach of the water. The breather pipe should be plugged. Every effort should be made to keep the flood water from entering and contaminating the well. A ring levy of clay mud and sand bags will hold back five feet of water if built wide enough.

(2) Surface Supplies

As flood waters reach the elevation at which the water plant's protection levies will be topped or a break may occur, the operator should begin to prepare the plant for shut down.

In all electric powered plants, the first step is the notification of the power company when the entire plant will be shut down. After emergency portable standby lighting equipment has been put in service, all switches controlling incoming electric power should be opened and tests made after the power is turned off to make sure that no electric current will reach the plant after flooding begins. Other precautions, such as removing gasoline and oil stored below high water level, should be taken. These materials, spread over the water surface create a fire hazard and make the cleaning of equipment difficult.

At steam powered plants the fires should be extinguished far enough in advance of the actual flooding of the boiler room to permit the firebox lining to cool. This will reduce the fractured damage to fire brick when it is suddenly subjected to cold water.

All readily removable items of equipment, chemicals and supplies should be secured out of danger.

(3) Distribution System

In order to cope with distribution system emergencies, special service vehicles should be available and equipped with two-way radios, hand or power operated valve keys, auxiliary generators for emergency lighting, pressure gauges, pipe and valve locaters and chlorination equipment.

Probably the most important item is a complete set of maps and notes showing reservoirs lay-outs, feeder mains, distribution mains, stream crossings and control valves at street intersections.

The loss of bridges and wash-outs may necessitate the shutdown of larger feeder mains. The shutting down of a large main is not a casual operation but one calling for speed, training, and previously planned procedure. There must be some means of knowing when a break occurs and or what main. This information should be transmitted to the repair crews as soon as possible. The man in charge of the crew should have a plan showing what valves are to be operated to effect the desired results. It should be pointed out that it may take three to four men up to thirty minutes to close manually operated 12-inch or 16-inch gate valves.

A flooded distribution system should not be polluted if the pressure has not been off in the system.

DISINFECTION OF MAINS

The principle causes of contamination are:

1. Main breaks;
2. Back-flow through faulty plumbing;
3. Cross-connections;
4. Reduced pressure within the system

There may be a tendency to overlook disinfection when the need for restoring services is grave. Regardless of the urgency, disinfection must be carried out. For the disinfection of contaminated mains the following procedure should be used:

1. Shut off main;
2. Repair main as soon as possible;
3. Thoroughly flush main of all sediment;
4. Inject 50 ppm chlorine and rest for 4 to 24 hours;
5. Flush main thoroughly;
6. Enter premises and instruct the occupants to flush the system by opening every faucet for fifteen minutes.

It is important to thoroughly cleanse and flush the mains before treatment is commenced. Disinfection of grossly contaminated mains may be facilitated by first slugging the system with a heavy dose of 200 to 250 ppm and following this by water containing 50 ppm for 4 to 24 hours. The chlorine may be applied by means of mobile chlorinating units or by using hypochlorite powder solution. Some operators prefer to use portable chlorination equipment rather than relying on the placing of hypochlorite in each length of pipe. Other operators prefer to keep all chlorination equipment at the water works and provide for disinfection of mains with the least amount of equipment.

The system can also be disinfected by raising the pH to 10.5 with common hydrated lime. When flushing the system it is necessary to see that the pH is 10.5 at all ends of the system.

EMERGENCY CHLORINATION METHODS:

A complete description of a temporary chlorine cylinder filling station from tank to cars is given in the September, 1954 issue of the AWWA Journal. The article written by Mr. B. L. Shera also describes how calcium hypochlorite solution can be made from lime and liquid chlorine.

The presence of chlorine is usually detected by means of orthotolidine. Chlorine residuals up to 10 ppm will give a yellow colour with orthotolidine. Residuals between 15 to 20 ppm give a bright red colour, and residuals of about 50 ppm give a brown precipitate with orthotolidine.

1. Direct Gas Feeding

A dry feed gas chlorinator consists essentially of a reducing valve and a rate of flow indicator. Fluctuations in gas pressure due to temperature variations of the liquid chlorine are minimizing by enclosing the cylinder within a vertical nest of cells through which pass tap water.

If a dry feed gas chlorinator is used to apply chlorine to an open flume, the diffuser on the end of the supply line should be submerged at least four feet and preferably six feet.

A chlorine cylinder without equipment may be used for direct feed during an emergency, controlling the rate by counting the bubbles per minute through a water trap. Low sensitivity of the cylinder valve limits the adjustment to about one-half pound per hour per cylinder.

A detailed description of one procedure using chlorine cylinders follows: Following the repair of the main, a section of pipe is left out so that a high velocity wash can be obtained to remove small stones and other debris. Two taps are made above the break and two chlorine diffusers are inserted. Chlorine cylinders are then connected to each diffuser. Chlorine is applied to the water used to wash out the line. Upon replacing the length of pipe which is removed for cleaning purposes a blow out valve or hydrant is opened at the end of the contaminated area. The pressure in the line should be kept under thirty pounds to permit direct feeding from the cylinders. Once a blood red residual is obtained, the blow-off or hydrant is closed and the line is allowed to stand for four to twelve hours. Then the water is blown off. The blow-off is closed when a residual of about 0.2 to 0.3 ppm is obtained. This system is useful only when the pressure is considerably less than that of the cylinders.

2. Hypochlorinators

Reciprocating pump-type hypochlorinators are applicable to water supplies ranging from 100 to 100,000 gallons per day. Injection pressures may reach 100 psi. Pumps are usually of the diaphragm type pulsating in a rubber, glass or plastic chamber.

3. Gravity Hypochlorite Solution Feeders

Chlorine solution can be fed into an open channel through an orifice tank having a float valve to maintain a constant solution level. The orifice tank has an orifice insert in the valved outlet union. The float is connected to a valve on the discharge line from a stock tank elevated above the orifice tank. Uniformity of feed is obtained by the constant level orifice tank which may be a toilet flush tank. The orifice may be made by inserting a corrosion resisting disc, having a hole and reamed to the proper size of the union.

For maximum simplicity, the hypochlorite solution can be fed with sufficient uniformity without constant level control provided the tank is above the orifice discharge. If the variation of the operating level in the tank is restricted to 2 feet, this elevation provides uniform dosage within 5 per cent. The orifice is merely a perforated cap into which a series of liners having various diameter openings may be inserted to vary the feed rate. Control may also be had by means of a stop valve.

REHABILITATION

All flood water and silt should be removed from reservoirs pumpwells and basements. The affected areas should then be disinfected with a strong chlorine solution (250 to 300 ppm). The floors and side walls should be scrubbed down thoroughly. All water used for scrubbing should then be removed.

Sand filters should be thoroughly washed and sterilized with a strong chlorine solution. When the filters and reservoirs are cleaned and placed in operation, chlorine residuals at the plant of 2 to 3 ppm should be maintained until bacteriological tests show that normal chlorination treatment can be safely resumed.

All flooded or damp motors and other electrical equipment should be thoroughly dried and inspected before re-use. Where necessary, new equipment should be installed.

Flooded motors are reconditioned by heating. This may be done by immersing the motor in hot parafin, placing it in an infra-red cabinet or using other lamp arrangements. After the East Chicago pumping station failure in January 1949, the flooded motors were first subjected to a current at low amperage and voltage, thus utilizing internal heat of the motors. Then, special lamps were used for the final drying.

New motors may sometime be dried with a blow torch if handled by an experienced electrician for care is needed to avoid burning of the insulation.

CONCLUSION

The importance of having a written plan of emergency procedure cannot be over emphasized. No matter how well thought out in advance, the plan must be available to every level when it is needed. The plan must be simple. It does no good to hand someone a thick book during an emergency; a couple of sheets of paper with some answers on them may be used. What is needed is a simple key to indicate where to look for things that have been carefully accumulated and to indicate emergency procedures that have been developed in advance.

The repair and treatment methods outlined in this lecture should be thoroughly understood and the procedures applicable to your system rehearsed periodically in order that they can be put into action quickly when required.

RECORDS AND REPORTS

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A record may be defined as a compilation or collection of figures, facts or data relating to an event or sequence of events. A report, on the other hand, is an explanation of the facts or figures that appear on a record.

RECORDS

The maintenance of records, or the collecting of figures to compile them is considered by many of us as a time-consuming task, a thing which someone thinks we should do, but for which many of us can see no important purpose.

Still, our very existence, professionally and otherwise, is one record after another and we maintain these records either mentally, to be forgotten as soon as the data is received, or kept in permanent form for future reference. Records are used, also, for the regulation of daily affairs and future planning. We all keep them and use them constantly, e.g. a bank book which aids in guiding present and future expenditures. If we do not maintain a bank account we have no money, or we bury our wealth in a hole in the ground. Even in the latter instance, we keep a record of where the burial spot is.

REPORT

Again, we accumulate records of our car mileage and how much gas we use. As soon as we calculate the miles per gallon of gas used, for someone's information, we are making a report based on the data collected from our car mileage records.

Instead, there is nothing peculiar about our maintaining records and preparing reports. Only the degree and the type of information desired differentiates between them.

We can apply the above to the operation of a water works or a water works system. The records we keep and the reports we make can be categorized as:

1. Operational records
2. Maintenance records
3. Statistical records
4. Accounting records

The information contained in each record may overlap depending upon how the record form is composed. Data of an operating nature may also relate to maintenance and/or statistics. This information will vary with the type of plant, the size of the plant and the method of treatment, the source of raw water and the extent of the distribution system. Data recorded may be on an hourly basis, semi-hourly, once a shift, twice a shift, weekly or monthly basis. Your records may be voluminous or sketchy, but in each case relative to what you want or need in order to operate your plant efficiently. Regardless of the form in which you are required to accumulate data, you will probably record additional information for your own broader understanding.

OPERATIONAL RECORDS

Treatment Plant

Records relating to the operation of the treatment plant may include information incorporating filter runs, wash water used, pumps in operation, chemicals used, condition of the raw and treated water, flows, chemicals on hand and on order, chlorination rates, power consumption, power factors, periods of maximum electrical demands, weather observations, and results of laboratory control tests used by you to assure the adequate treatment of the water delivered by the plant. If your initial supply is from wells, you will be interested in recording well drawdowns and rates of aquifer replenishment. If your supply is from streams or lakes you will, no doubt, desire to record stream levels or lake levels.

In order to set up a system of adequate records, two essential elements must be remembered. Firstly, the form and extent of the records to be kept must be carefully planned. Secondly, a procedure must be established to ensure the continuance of the records selected. This is most important, because a given set of operating conditions, if not recorded immediately, can never be accurately reproduced.

OPERATIONAL RECORDS

Distributing Systems

In the case of distributing systems, the records relating to the operation and maintenance of the system are not static and definite procedures to ensure that information will flow from the field to the control point are necessary. A record of primary significance to the operating and maintenance of a distribution system is a comprehensive map. This map should be on as large a scale as possible, and should show all mains, main sizes, types of mains, valves, hydrants, streets, reservoirs, elevated tanks, wells, booster stations and emergency inter-connections with other systems. If possible, blow-offs, air release valves and normally closed gate valves should be indicated. The original map should be carefully stored and copies issued to operating personnel for their use. As the map must include the entire system, the scale may be too small to show the required detail. Therefore, to have an adequate record it will probably be necessary to divide the map into sections on separate sheets, using an adequate scale to show the requisite detail. Sectional maps must be accurately scaled so that adjoining sheets will coincide. Information on sectional maps will show subdivisions, lots, blocks, tracts, streets and easements, street names and widths, mains, size of mains, locations, material, year installed, hydrants, type, class of hydrants, details relating to valves, service lines including size and location, and all other pertinent information relating to the system or section of the system under study. In other words, the section map is a magnified part of the major system map which enables you to read the fine print. In large distribution systems, it has often been found advisable to enlarge or divide section maps for issuance to works foremen assigned to particularly congested areas. In preparing a section map it may not be possible to obtain all the desired information in an economically short time. This information may be omitted until it can be obtained without undue expense.

VALVE RECORDS

In any event, sectional maps are among the most important of all distribution system records. Supplementing these maps, and for use of the field crews, are valve records. Valve records are lists of all gate valves with their location, function and operation. Data is given as to valve number, size, make, class, number of turns to open, direction of turns to open, street location, distance and direction from the principal street line or curb and intersection, or other information to help rapidly locate the correct valve.

MAINTENANCE RECORDS

Maintenance records on each section of main, each valve, hydrant, or blow-off on the system can be set up to show the trouble experienced, remedy, time and material required to effect repairs, and the costs involved. By accumulating records of this nature, it is possible for supervisory personnel to evaluate types of material or equipment, forecast future trouble spots, set up preventative maintenance procedures and prepare maintenance budgets. Maintenance records can be most easily compiled and kept as a running record by employing card reference files. The use of cards will:

- (a) Simplify the procedure to be adopted for adequate maintenance and lubrication of all equipment.
- (b) Establish correct time intervals between lubrication of equipment.
- (c) Establish a policy of preventative maintenance for all equipment.
- (d) Establish, where possible, a standardization of maintenance practices and lubricants for more efficient and economical operation of plants.
- (e) Remove from the operator the burden of remembering when maintenance and/or lubrication should be carried out.
- (f) Provide an accurate lubrication record of each unit or piece of equipment.

Information on the card usually includes all pertinent information relative to the unit to which it refers. Each unit will have a card which will identify the equipment by a plant number and will list name plate data, model, serial number, manufacturer, supplier service representative, lubrication instructions by type and grade of lubricant and frequency of lubrication. A category on the card is for a brief description of repairs made, parts replaced, servicing and repair costs. Some operators colour code the cards for lubrication inspection or overhaul periods. The use of coloured cards will enable the operator to identify quickly equipment requiring various intervals of inspections, routine maintenance and lubrication. Periodic spot checks by the plant superintendent will give immediate indication of whether routine maintenance instructions are being carried out.

STATISTICAL RECORDS

Much of the data accumulated on daily operating log sheets may be classed as statistical in nature. Such data deals with hourly flows, maximum and minimum flows, total flows, power consumption, quantities of chemicals used, water conditions, periods and times of maximum power demands, hours of pump operation, and many other factors that can be compared with past records and be used for forecasting future operating conditions. Close comparison of these figures show many interesting features. For instance, it has been possible by the collation of total flows to indicate to main crews that a leak has occurred in the distribution system. Cost of operation, total flows and plant capacity will provide data which may influence the provision of meters in the system or metered supplies to the users. Periods of maximum power demand will give you clues as to when to start auxiliary, mechanically driven pumping units, thereby reducing monthly power bills and, in turn, plant operating costs. Total flows or maximum flows may indicate the necessity for increasing plant capacity or revising plant design.

ACCOUNTING RECORDS

All accounting records may not come under the jurisdiction of the plant operator, but information including inventory control, costs of maintenance, and time or payroll data do. From the point of view of the operator, the payroll records are highly important. If they are not accurate, and if they are not submitted to the central accounting point on time, he, necessarily, will receive complaints. With the development of machine accounting, many of the major accounting records are maintained in the form of punched cards. The advantage of punched cards is that much information can be included on them in a small space. Later, these cards can be used for billing procedures and collection data.

DAILY LOG BOOK

Another useful record is the diary or daily log book. Many miscellaneous incidents in plant operation do not fit into the regular records employed; however, they should be kept in some type of permanent form. Such information noted might include: occasional numerical data and measurements, maintenance items, replacements and repairs, start-ups, trouble and various methods tried for correction in start-ups or treatment, complaints

from customers, visits by officials or authorities and their comments, reports from other agencies such as the Department of Health re inspections and tests, and similar facts that an operator always appreciates having on hand. This data may be quickly referred to if the daily summary sheet of operation contains a cross reference. Instances arise where knowledge of the data of an occurrence, even without further detail, is helpful.

In this dissertation, I have not attempted to relate what records should be kept, what data should be recorded, or how often data should be recorded. I have merely indicated a few suggestions as to what some operators may keep in the form of records. In the final analysis, the records you keep will depend on the type of plant you operate, the amount and category of information you require for answers to inquiries, and what information will enable you to operate the plant efficiently and economically. I have also tried to stress the great importance of accuracy and the need for continuity in your records. Also, attention has been directed to some of the ways in which this information is used. Finally, if records are carefully assembled and analyzed, they can be of much assistance to you and to your supervisors.

BASIC FLUID MECHANICS

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INTRODUCTION

Fluid mechanics is the study of all fluids under all possible conditions of rest and motion. It has stemmed in recent years from the subject of hydraulics which covered only a study of liquids and was largely empirical in nature. The newer, rational approach to fluid behaviour is based upon the classical principles of mathematics and physics.

In the first lecture and the two following lectures on the subsequent operators courses, we will build upon your knowledge of arithmetic, algebra, and physics to explain and demonstrate certain basic principles of fluid statics and fluid flow considering water as the fluid. Once the basic principles are understood, we will apply them to practical problems encountered both in the distribution system and at the water treatment plant.

On this basic course, we will consider some fundamental properties of fluids, water pressure, and pressure measurement. The lecture and demonstrations on the Intermediate Course will cover the basic principles of water flowing in pressure conduits, flow measurement, and flow tests on the distribution system. The third presentation will concentrate on the hydraulics of filtering and backwashing rapid sand filters.

The flow of water in pipes or channels when not under pressure is limited in the water works field to some gravity supply lines and to conduits in gravity treatment plants. Therefore, open channel flow will not be discussed because of its lack of application for most operators in attendance.

PROPERTIES OF FLUIDS

The properties of fluids to be considered are weight, mass, specific weight, specific gravity, viscosity, and vapour pressure.

Weight (w)

Every body in the universe exerts a force of gravitational attraction on every other body. The force of gravitational attraction which the earth exerts on a body is called the weight of the body.

Thus, the statement that a man weights 160 pounds is equivalent to stating that he is attracted by the earth with a force of 160 pounds. Since the weight of a body is a force it must be expressed in force units which is "pounds" in the English system.

The force of gravitational attraction between two bodies decreases as the distance between them increases. Therefore, the weight of a body is not an unchangeable property of a body but diminishes as the elevation of the body is increased, because of the increased distance to the earth's center.

Mass (M)

The term mass as used in mechanics refers to that property of matter which in everyday language is described by the word "inertia". We know from experience that an object at rest will never start to move by itself-a push or pull must be exerted on it by some other body. "Inertia", therefore, is that property of matter because of which a force must be exerted to accelerate it. (Newton's Second Law $F = Ma$, 1686).

The mass of a body is an unchanging property of the body independent on its velocity, acceleration, or height above the earth's surface.

It is found by weighing the object and dividing by the corresponding value of the acceleration of gravity (g)

$$M = \frac{w}{g}$$

In the English force unit system, mass units are called "slugs". Since M is fixed, the acceleration of gravity varies in direct proportion to the variation in

a body's weight. This is the reason that "g" is smaller at high altitudes than at the earth's surface.

On or near the earth's surface the gravitational force is nearly constant. The acceleration of gravity "g" in the English force unit system is usually taken as 32.2 feet per second per second.

Specific Weight (W)

Unit or specific weight is the weight of a fluid contained in a unit volume. It is expressed in the English system of dimensions as pounds per cubic foot.

The specific weight of water changes only slightly with pressure but varies appreciably with temperature. It is greatest at 4°C i.e. 39.2°F being 62.45 pounds per cubic foot. At 80°F it is only 62.22 pounds per cubic foot.

Specific Gravity (s)

Specific gravity is the dimensionless ratio of the specific weight of the fluid in question to the specific weight of distilled water at 4°C and atmospheric pressure. The specific gravity of water at the standard temperature and pressure is 1.0.

Specific Gravities "S" of Some Liquids at Room Temperature (68°F) (Referred to water at 39.2°F)

Water	0.998
Mercury	13.546
Ethyl Alcohol	0.789

The specific weight of other liquids may be readily calculated by the expression:

$$W \text{ (lb./ft.}^3\text{)} = S \times 62.45 \text{ (lb./ft.}^3\text{)}$$

It is very important to use the correct units for the known factors when solving equations, otherwise the answers will not be correct.

Viscosity ($\mu = \mu$)

Viscosity is that property of a fluid which causes resistance to flow. It may be thought of as the internal friction of a fluid. In the liquid state the molecules are packed as closely together as possible and the viscosity is apparently due to the cohesiveness of the molecules. As the temperature is increased, the cohesion decreases and the viscosity decreases.

Viscosity μ (μ) has the dimensions of lb. sec./ft.². Under ordinary conditions of pressure viscosity has been found to vary only with temperature.

Viscosities " μ " of Some Liquids (68°F)

	<u>$\mu \times 10^{-5}$ lb. sec./ft.²</u>
Water	2.1
Mercury	3.2
Ethyl Alcohol	2.3

The significance of viscosity will be discussed on the Intermediate Course while studying fluid flow and on the Senior Course while considering backwash rates.

Vapour Pressure

All liquids tend to evaporate or vapourize which they do by projecting molecules into the space above their surfaces. Such molecules, being gaseous, are capable of exerting a partial pressure, the "vapour pressure" of the liquid. Since this pressure is dependent primarily upon molecular activity it will increase with increasing temperature.

For boiling to occur, a liquid's temperature must be raised sufficiently for the vapour pressure to become equal to the pressure imposed on the liquid. Thus, the boiling point of a liquid is dependent upon its pressure as well as upon its temperature.

Vapour Pressure of Some Liquids (68°F)

	<u>psi</u>
Water	0.339
Mercury	0.000,025
Ethyl alcohol	0.850

The table shows the great value of mercury in the barometer where there is almost a perfect vacuum at the top of the column since the vapour pressure is only 0.000,025 psi. It also shows that a greater pressure must be maintained on gasoline to prevent its boiling or evaporating than is the case for water.

HYDROSTATICS

Hydrostatics is the branch of fluid mechanics which deals with the pressures and forces resulting from the weight of a fluid at rest. In the second part of this presentation we will consider fluid pressure, the mercury barometer, the absolute and gauge pressure systems, the Bourdon gauge, and manometers.

Fluid Pressure

By pressure is meant the force exerted on a unit area. It is usually expressed in the English System as lbs./in² (psi) or lbs./ft.² (psf).

A fluid confined in a vessel exerts forces against the walls of the vessel. By Newton's Third Law (action and reaction are equal and opposite) the walls exert oppositely directed forces on the confined fluid.

As we will demonstrate, the magnitude of the pressure at any point is equal to the product of the vertical distance below the surface and the specific weight of the liquid.

$$P = WH$$

where P is the pressure in lb./ft.²
 W is the specific weight lb./ft.³
 H is the distance from the liquid surface to the point of pressure in ft.

also $H = P/W$ = the pressure head.

It expresses the depth in feet of a liquid of a unit weight W required to produce a pressure P.

All points in a connected body of fluid at rest are under the same pressure if they are at the same depth. The pressure is independent of the size or shape of the container. Also, as we shall demonstrate, the pressure is the same in all directions as first postulated by the French scientist Pascal in the mid 17th century.

Absolute and Gauge Pressure

As indicated previously pressure, which is force per unit area, is expressed in a number of different ways such as pounds per square foot (psf) or pounds per square inch (psi). Such a pressure, however, must be with respect to some datum or reference pressure.

Most pressure-measuring devices read in terms of gauge pressure—that is, the pressure relative to the surrounding atmospheric pressure. This is because practically all pressure gauges read zero when open to the atmosphere and read only the difference between the pressure of the fluid to which they are connected and that of the surrounding air.

If the pressure is below that of the atmosphere, it is designated as a vacuum and its gauge value is the amount by which it is below that of the atmosphere. The atmospheric pressure is also called the barometric pressure and varies with the altitude. As we will show you shortly, atmospheric pressure at mean sea level and standard conditions is considered to be 14.7 psia (pounds per square inch absolute).

Pressure can, therefore, be measured above absolute zero. All values of absolute pressure are positive as a negative value would indicate tension, which is normally considered impossible in any fluid. A perfect vacuum would correspond to absolute zero pressure.

The two systems of pressure measurement may be converted from one to the other by the following expression:

$$\text{Absolute pressure} = \text{Atmospheric pressure} \begin{matrix} -\text{Vacuum} \\ +\text{Gauge} \\ \text{Pressure} \end{matrix}$$

These relationships are illustrated in Figure 2.

Example:

A Bourdon gauge registers a vacuum of 12.5 inches of mercury when the barometric pressure is 14.5 psi. What is the absolute pressure?

$$\begin{aligned}
 \text{Absolute pressure} &= \text{Atmospheric pressure} - \text{Vacuum} \\
 &= 14.50 \text{ (psi)} - 12.5 \text{ (inches)} \times \\
 &\quad \frac{14.7 \text{ (psi)}}{29.9 \text{ (inches)}} \\
 &= 14.50 \text{ (psi)} - 6.15 \text{ (psi)} \\
 &= 8.35 \text{ (psi)}
 \end{aligned}$$

Mercury Barometer

The mercury barometer (Figure 3) is used to measure absolute pressure. The mercury barometer is constructed by filling the tube with air-free mercury and inverting it with its open end beneath the mercury surface of the receptacle.

Vaporization of the mercury being neglected, the space in the top of the tube is thus completely evacuated and there is nothing whatever to exert pressure in the space thus the pressure here is the lowest possible, called "absolute zero".

Since the mercury column H is in balance with the atmospheric pressure and since the pressure at the top of the column is close to "absolute zero", it is evident that the length of the column is a direct measure of "pressure above absolute zero" or "absolute pressure".

If p = atmospheric pressure = 14.7 psi. (The atmospheric pressure varies somewhat with weather and altitude).

$$\begin{aligned}
 H &= p/W \\
 &= \frac{14.7 \text{ lbs./in.}^2 \times 144 \times \text{in.}^2/\text{ft.}^2}{13.54 \times 62.45 \text{ lbs./ft.}^3} = 2.50 \text{ ft.} \\
 &= 29.9 \text{ in.}
 \end{aligned}$$

If the column is of water and the vapour pressure of the water is neglected:

$$H = \frac{14.7 \times 144}{62.45} = 33.9 \text{ feet}$$

If the pressure p is 1 psi

$$H = \frac{1 \times 144}{62.45} = 2.31 \text{ feet}$$

It should be remembered that standard atmospheric pressure is approximately 14.7 psi, 29.9 inches of mercury, and 33.9 feet of water. Also, 1 psi is approximately equal to 2.31 feet of water.

Bourdon Gauge

The Bourdon Gauge (Figure 4) is an instrument for measuring gauge pressure. The pressure is introduced into a curved, hollow metal tube which is usually made of brass. One end of the tube is fixed to the frame of the gauge. The remainder of the tube is free to move. As the pressure introduced into the gauge is increased, the tube gradually straightens, the free end moving in proportion to the internal pressure. The pointer is thus activated to indicate the pressure on the face of the gauge.

Such gauges are calibrated to read in pounds per square inch, pounds per square foot, or inches of mercury or feet of water. The gauges can be made to give results with 1/2 per cent over the range for which they are calibrated. The average commercial gauge, however, is likely to register no closer than 5 or 10 per cent. Greater precision can be obtained in increasing the diameter of the gauge or by decreasing its range. Error due to mechanical friction within the mechanism can be minimized by tapping the gauge with the finger or a pencil just prior to taking a reading.

Because of the inertia of moving parts and of the fluid column, rapid pressure fluctuations cannot be followed with precision. If the gauge is subjected to a very high pressure the metal in the tube can be strained beyond the elastic limit and a permanent set will take place. The calibration is no longer valid but when this occurs the indicator hand reads greater than zero when the pressure is the same on both inside and outside the tube. Some gauges have a movable scale to permit the zero reading to be set for any desired pressure.

A pressure and vacuum gauge combined into one is known as a compound gauge. The pressure indicated by a gauge is assumed to be that at its centre. If the connecting piping is filled completely with fluid of the same density as that in A (Figure 5) then:

$$\frac{PA}{W} = \frac{144}{W} \times \text{psi} + Z$$

For vacuums -

$$\frac{PA}{W} = Z - \frac{S}{12} \times \text{in. Hg}$$

Demonstrations of these relationships as well as the Bourdon Gauge are outlined in the Supplement to the notes.

Piezometers

A piezometer (Figure 6) is a very simple device for measuring moderate pressure of liquids. It consists of a tube in which the liquid can freely rise without overflowing. The height in the tube will give the pressure head directly.

To reduce capillary error the tube diameter should be at least 1/2 inch. The hole must be drilled absolutely normal to the interior surface of the wall and the tube must not project beyond the surface. The hole should be very small, not over 1/8 inch for small pipes and not more than 1/4 inch for very large pipes.

Simple Manometers

Manometers are tubes attached to reservoirs, pipes or channels for the purpose of measuring the pressure. The equations of hydrostatics are used to determine pressures from manometer readings even though manometers are most frequently used to measure pressures in moving fluids. The manometer liquid most commonly used is mercury.

As indicated above, when the manometers contain only the fluid in the conduit they are frequently called piezometers. Piezometers are very sensitive pressure gauges but are impractical for the measurement of high pressures because of the excessive length of tube required.

Consider the U-tube manometer (Figure 7) in which all distances and unit weights are known and pressure P_x is to be found.

Since over horizontal planes within continuous columns of the same fluid pressures are equal, $P_1 = P_2$ and

$$P_1 = P_x + WL \text{ and } P_2 = 0 + W_1H$$

$$P_x + WL = W_1H$$

$$\text{and } P_x = W_1H - WL$$

For more complicated gauges it is helpful to commence the equation at the open end of the manometer with the pressure there, then proceed through the tube to the unknown pressure point adding terms when descending and subtracting, when ascending and equating the result to the unknown head. Using this method for the U-tube of Figure 7:

$$0 + W_1H - WL = P_x$$

$$\text{i.e. } P_x = W_1H - WL$$

If the absolute head is desired, then the zero of the first term will be replaced by the atmospheric pressure head. It is essential to take into account the specific weight of the fluid in the connecting tube if it is different from that of the fluid of unknown pressure.

In measuring a vacuum, the manometer arrangement shown in Figure 8 should be used to permit air or vapour from collecting in the tubing. For this case:

$$0 - \frac{20}{12} W \text{ mercury} - \frac{8}{12} W \text{ water} = P_W$$

$$P_W = - \left(\frac{20}{12} \times 13.6 \times 62.4 \right) - \left(\frac{8}{12} \times 1 \times 62.4 \right)$$

$$= - 1414 - 41$$

$$= - 1455 \text{ psf gauge}$$

$$\text{or } - 10.1 \text{ psi gauge}$$

Differential Manometers

Differential manometers are frequently used to measure the difference between two unknown pressures P_x and P_y as in Figure 9.

In writing the gauge equation for the differential manometer, there is no open end at which to start. One may, however, commence at the left unknown and set the terms down-positive and negative as before-equating the result to the other end pressure.

$$P_x + W_1L_1 - W_3H - W_2L_2 = P_y$$

$$P_x - P_y = W_2L_2 + W_3H - W_1L_1$$

The alternative method as before is to equate P_4 to P_5 and

$$P_x + W_1L_1 = P_y + W_2L_2 + W_3H$$

$$\text{and } P_x - P_y = W_2L_2 + W_3H - W_1L_1$$

BASIC FLUID MECHANICS-DEMONSTRATIONS

No. 1: SPECIFIC WEIGHT OF WATER

The first demonstration is to determine the weight of a cubic foot of water at room temperature using a cylinder, rule, scales, and bucket of water.

Method

1. Determine the diameter of the cylinder in inches;
2. Convert diameter to feet;
3. Find height to fill cylinder in feet to hold one cubic foot of water;

$$V = \frac{\pi d^2 h}{4} \quad \text{where} \quad \pi = 3.14$$

$$h = \frac{V \times 4}{\pi d^2}$$

4. Convert h to inches and mark cylinder;
5. Weigh cylinder empty and record weight in ounces;
6. Fill cylinder with water to the mark;
7. Weigh cylinder on scales in pounds and ounces;
8. Find weight of one cubic foot of water in pounds by difference and converting ounces to a decimal fraction of a pound (1 lb. = 16 oz.);
9. Answer = lbs./ft.³.

NO. 2: SPECIFIC GRAVITY OF SALT SOLUTION

The second demonstration is to determine the specific gravity of a salt solution using first a bottle and scale and second a hydrometer and container.

Method A

1. Weigh the empty bottle;
2. Fill it to overflowing with water;
3. Wipe off water and weigh again;
4. Empty the water, fill with salt water as before and weigh again;
5. Arrange results as follows;

Weight of empty bottle	=	ounces
Weight of bottle with water	=	
Weight of bottle with salt solution	=	
Weight of water	=	
Weight of salt solution	=	

S.G. of salt solution = $\frac{\text{Weight of salt solution}}{\text{Weight of water}}$

Method B

1. Fill container with water;
2. Insert hydrometer and take reading;
3. Empty the water and fill with salt solution;
4. Insert hydrometer and take reading;
5. The S.G. of the salt solution = $\frac{\text{Reading with salt solution}}{\text{Reading with water}}$

NOTE: The hydrometer is marked to show the volume and thus weight of water it displaces which is equal to the weight of the hydrometer itself. (Archimedes Principle).

6. Compare the results.

NO. 3: FLUID PRESSURE

This experiment is to prove that in a liquid at rest under gravity the pressure exerted is proportional to the depth, is the same in all directions, and is independent of the volume of liquid used.

Apparatus

The pressure gauge consists of a small glass funnel (or thistle tube) A (Figure 10) over which is tied a thin sheet of rubber. A rubber tube D connects the funnel to a U-shaped glass tube F, of small bore, in which is coloured water or aniline oil which acts as a manometer. An increase of pressure on the sheet rubber forces it inwards and this will cause a difference in the levels of the liquid in the manometer, the amount of which can be measured. The thistle-tube is fastened to the lower end of a rule in such a way that it can turn about a horizontal axis in the plane of the rubber. In this way the rubber sheet may be made to face any direction.

Method

Lower the funnel into the water (which should be at the same temperature as the room) until 3 inches below the surface. Note the depth and observe the difference in the levels of the liquid in the manometer. By means of a wire attached to the funnel turn it so that it faces in different directions, and observe any change in the manometer. Be careful not to kink the tube.

Lower the funnel 3 inches further; note the depth and the difference in the levels. Rotate as before and observe the manometer reading. Continue this until the bottom of the vessel is reached.

Next, use a vessel of smaller cross-section and repeat the operations. Tabulate the results in each case. Draw a curve in which ordinates represent depths of the rubber sheet and abscissas represent differences in the levels in the manometer. Determine the relationship between depth and pressure.

NO. 4: ATMOSPHERIC PRESSURE

This experiment is to measure the pressure exerted by the atmosphere using a mercury barometer (Figure 3).

Apparatus

A heavy glass tube about 40 inches long, closed at one end (the internal diameter of the tube should be at least $\frac{1}{4}$ inch); mercury; dish.

Method

Pour mercury into the tube until it is nearly filled. Hold the finger over the open end and invert the tube several times in order to collect the air bubbles, although the air cannot be fully eliminated without boiling the mercury in the tube, and to do this requires special apparatus. Then, complete the filling of the tube, placing the open end under the surface of mercury in a dish. Support the tube in a vertical position and measure the height of the mercury in the tube above that in the dish in inches. Express the atmospheric pressure in psi.

NO. 5: BOURDON PRESSURE GAUGE

This demonstration is to study the Bourdon Gauge (Figure 4) by taking one apart, examining it, and determining how to calibrate it.

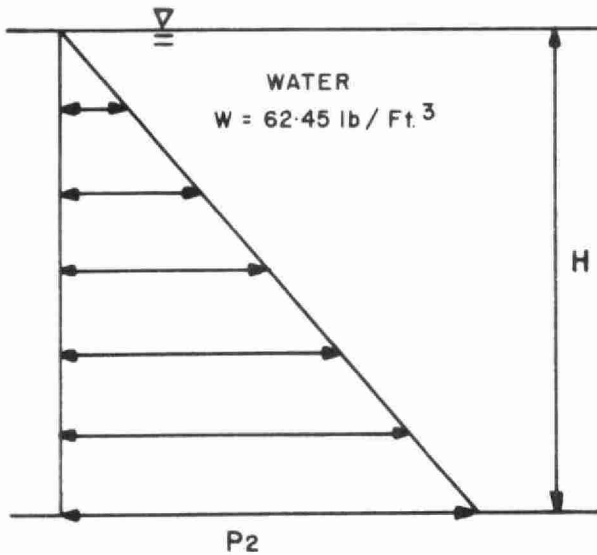
Correcting positive pressure gauge readings relative to various datum planes (Figure 5) will also be demonstrated using apparatus similar to that for No. 3.

NO. 6: UNDERSTANDING VACUUM READINGS

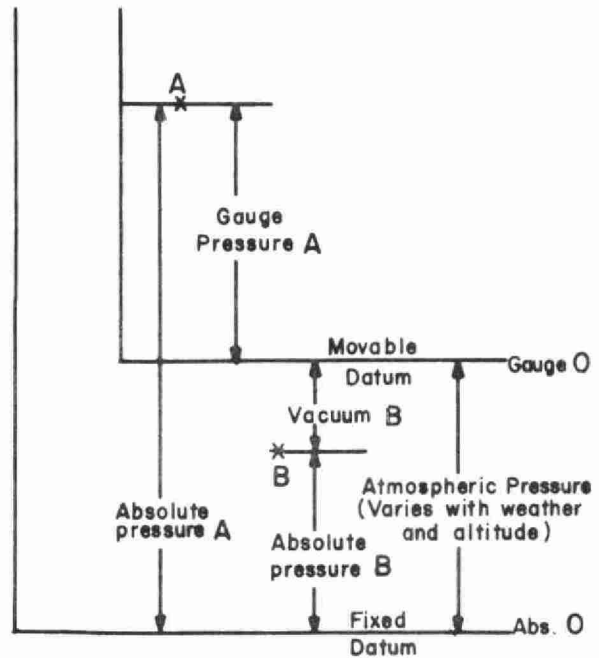
The apparatus shown in Figure 11 will be used to demonstrate differences in vacuum gauge readings by adjusting the elevation of the mercury manometer connected to the suction line of the pump.

Readings at different levels will be recorded and compared with the results of No. 3 and No. 6.

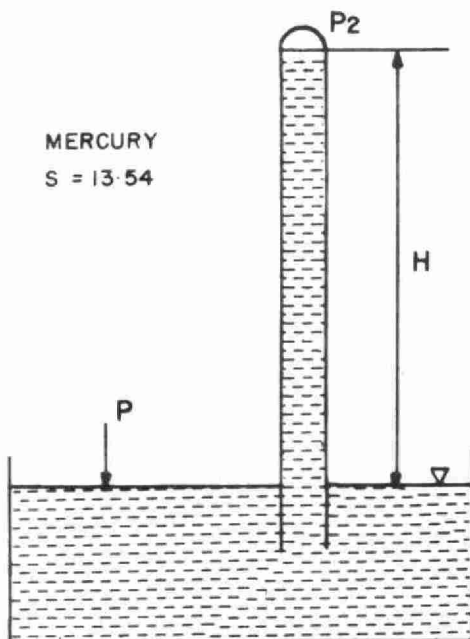
BASIC FLUID MECHANICS
LECTURE NOTES (SHEET No. 1)



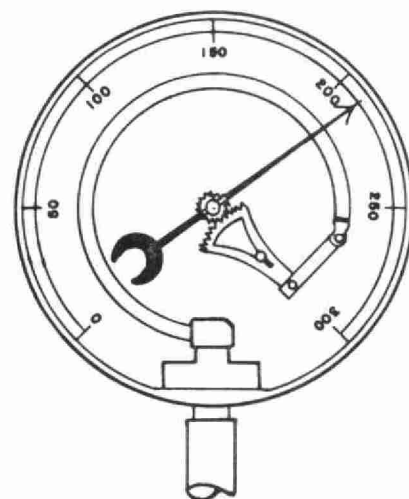
FLUID PRESSURE
FIG. 1



ABSOLUTE GAUGE PRESSURES
FIG. 2

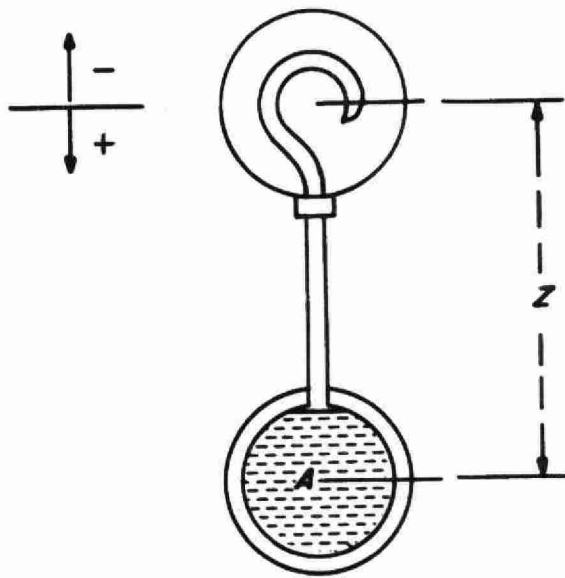


MERCURY BAROMETER
FIG. 3

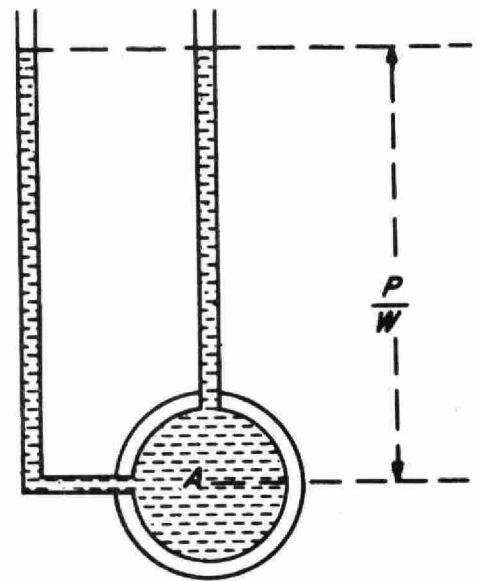


BOURDON GAUGE
FIG. 4

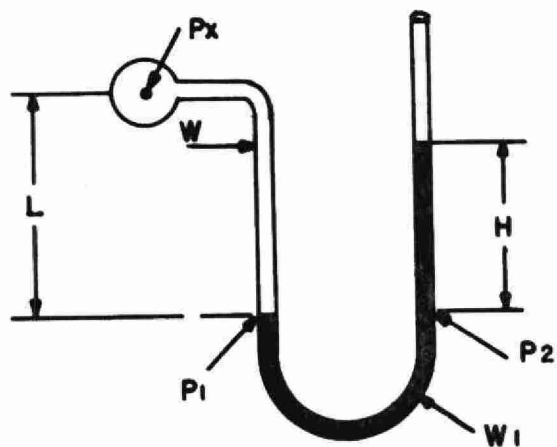
I - 17
 BASIC FLUID MECHANICS
 LECTURE NOTES (SHEET No.2)



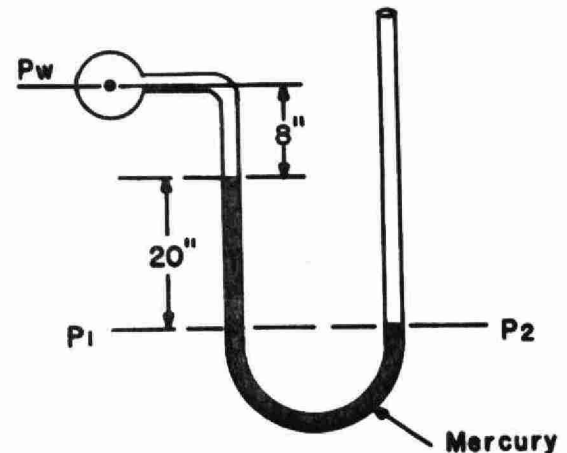
BOURDON GAUGE
 ELEVATION CORRECTION
 FIG. 5



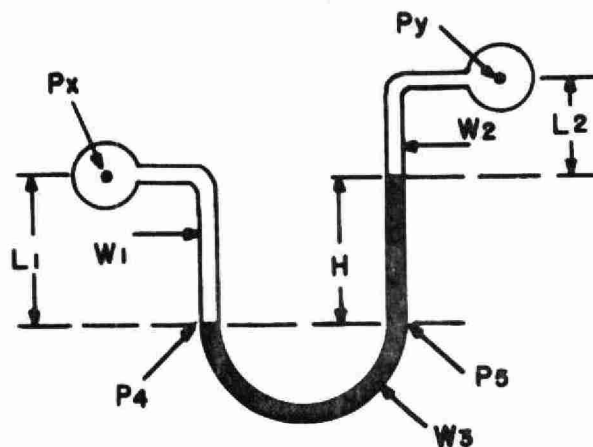
PIEZOMETERS
 FIG. 6



SIMPLE MANOMETER (PRESSURE)
 FIG. 7

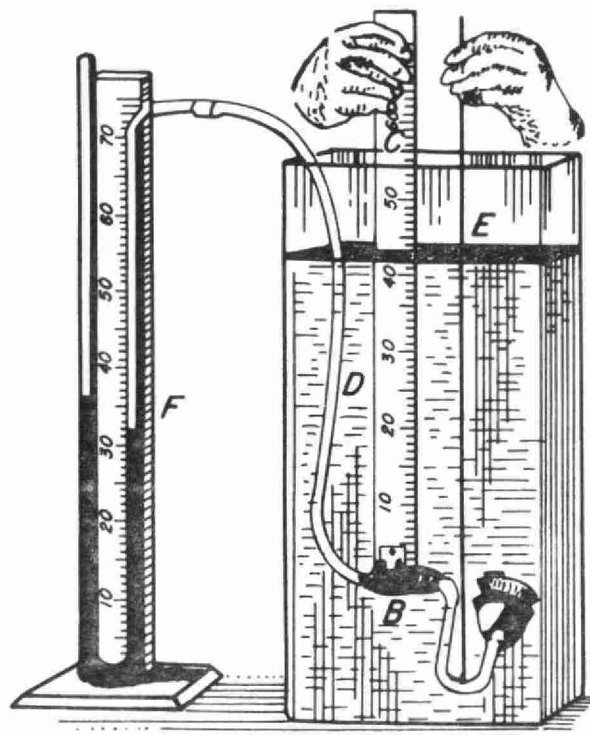


SIMPLE MANOMETER (VACUUM)
 FIG. 8

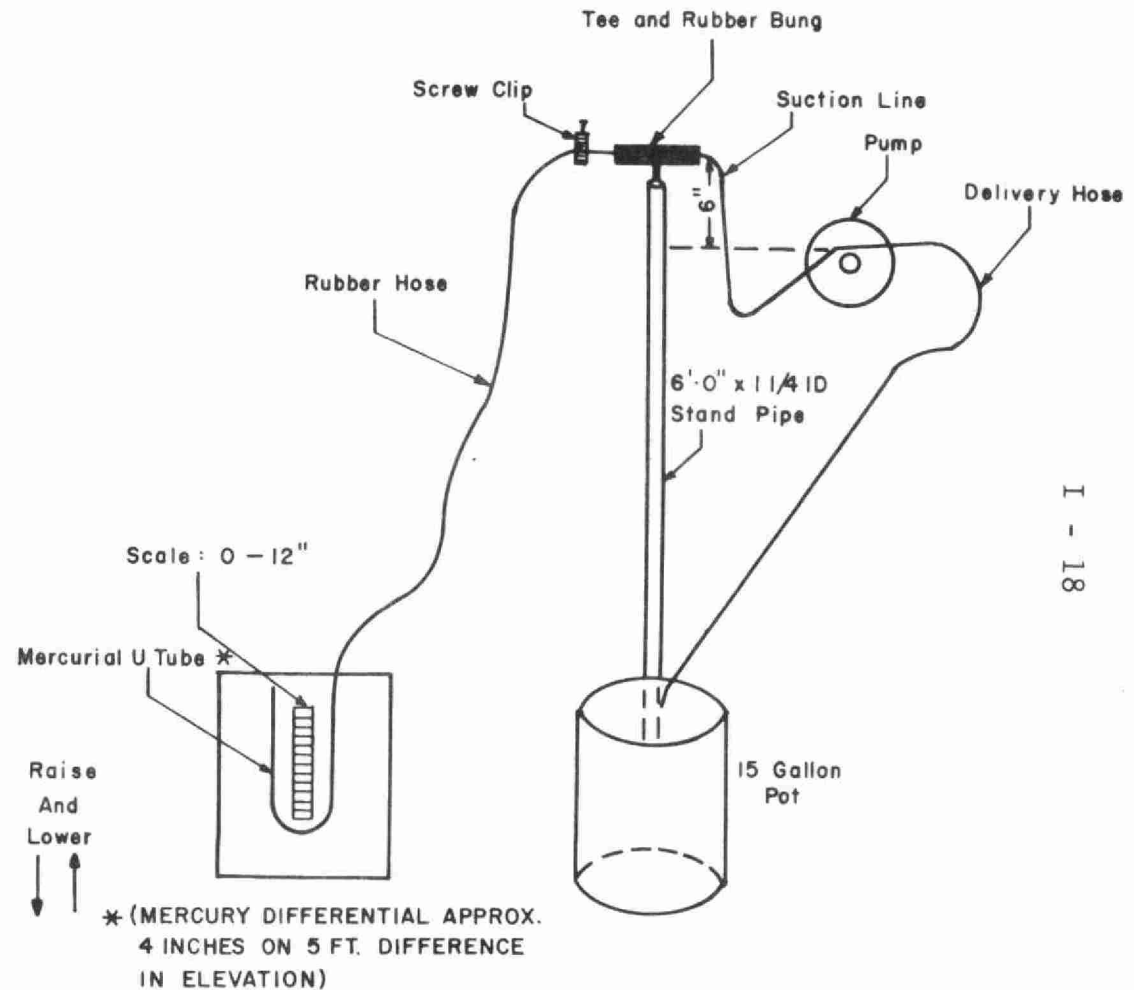


DIFFERENTIAL MANOMETER
 FIG. 9

BASIC FLUID MECHANICS — DEMONSTRATIONS (SHEET No.3)
(APPARATUS TO SHOW HOW TO CORRECT VACUUM GAUGE READINGS TO DIFFERENT DATUM)



**APPARATUS TO SHOW THAT
PRESSURE IS PROPORTIONAL TO
DEPTH AND IS THE SAME IN
ALL DIRECTIONS FIG. 10**



**UNDERSTANDING VACUUM GAUGE READINGS
FIG. 11**

OPERATION AND MAINTENANCE
OF PUMPS AND MOTORS

A. B. Patterson, Director

James F. MacLaren Limited

PUMP OPERATION

Pumps, like people, act differently under different conditions. To select pumps intelligently and operate them efficiently requires an understanding of what may and may not be expected of them.

In order that you may all understand the basic fundamentals of centrifugal pumps, I propose to have you prepare a characteristic curve for a typical centrifugal pump using test data which is provided.

(At this point all candidates prepared a Head-Capacity Curve)

Now we have in simple graphic form a picture of what will happen under any specified condition. The data for this curve must be carefully measured by an actual test and is always available from the manufacturer. As pump operators, you should know where these curves are and how to use them.

The pump we are considering is one of constant speed. As operators, you are aware that it is sometimes necessary to change the discharge pressure or head against which this pump must operate. Such changes may be brought about by any one of the following conditions:

- (a) Installation of a new and larger feeder main from the pumping station resulting in lower back pressure.
- (b) Installation of a new tank or reservoir into the pumping district with a resultant change of head.
- (c) Installation of additional pumping capacity into a station resulting in a greater back pressure or pump head.

We would expect that the engineers or suppliers would be called in to help with this problem, but I feel that as operators you should know the basic facts and be prepared to enter into an intelligent discussion. This is not difficult. Three simple rules are involved, and I would suggest that they be committed to memory. They are:

- (1) Capacity of a unit varies directly as the impeller diameter ratio.
- (2) Head varies directly as the (impeller diameter ratio)².
- (3) Power varies directly as the (impeller diameter ratio)³.

A simple way to remember these is to arrange the three key words in alphabetical order and then number them - 1, 2 and 3 - as follows:

- 1 - Capacity
- 2 - Head
- 3 - Power

Returning now to the characteristic curve data, we note that at a capacity of 4,000 g.p.m. the unit will operate at a head of 140 ft., an efficiency of 87%, and consume 163 brake H.P.

Assuming that the new impeller diameter will be 11.5 inches as compared with the existing impeller diameter of 12 inches, we are now able to predict the new pump characteristics at the reduced impeller size.

The basic ratio is -

$$\frac{\text{New Capacity}}{\text{Old Capacity}} \quad \text{as} \quad \frac{\text{New Impeller Diameter}}{\text{Old Impeller Diameter}}$$

We know three of the four values; therefore, let X equal the unknown and we can easily solve for X.

Capacity: Let X = New Capacity resulting from the smaller Impeller diameter.

$$\begin{aligned} \frac{X}{4000} &= \frac{11.5''}{12.0''} \\ X &= \frac{11.5}{12} \times 4000 = 0.958 \times 4000 \\ &= 3,832 \text{ G.P.M.} \end{aligned}$$

Head: Let X = New Head resulting from the smaller Impeller diameter.

$$\frac{X}{140} = \left[\frac{11.5''}{12.0''} \right]^2$$

$$X = \left[\frac{11.5}{12.0} \right]^2 \times 140 = 0.918 \times 140 = 129 \text{ ft.}$$

Power: Let X = New Horsepower requirement resulting from the smaller Impeller diameter.

$$\frac{X}{163} = \left[\frac{11.5''}{12.0''} \right]^3$$

$$X = \left[\frac{11.5}{12.0} \right]^3 \times 163 = 0.879 \times 163 = 143 \text{ B.H.P.}$$

To sum up, we now know that an impeller reduced from 12.0 inches in diameter to 11.5 inches in diameter will change the pump characteristics as follows:

Capacity from 4,000 G.P.M. to 3,832 G.P.M.

Head from 140 feet to 129 feet.

Power requirement from 163 B.H.P. to 143 B.H.P.

The efficiency, for all practical purposes, will remain the same.

PUMP INSTALLATION AND OPERATION

(1) Pump Piping

Never use pipe smaller than the pump nozzles, and preferably use larger, especially on the suction side. Use eccentric reducers from the larger suction pipe to the pump nozzle to prevent formation of air pockets in the pipe. Suitable tapered reducers on the suction and increasers on the discharge will ensure efficient flow on the system and conserve power. Run all piping as directly as possible and with a minimum of elbows and other fittings.

Never place a pipe-line elbow in a horizontal plane directly at the pump suction nozzle. Between the elbow and the suction nozzle, use a piece of straight pipe at least four to six pipe diameters long. An elbow attached in a horizontal

plane directly at the pump suction tends to cause unequal thrust and hydraulic losses due to the liquid filling one side of the suction chamber and impeller eye more than the other.

Whenever possible the suction reducer and the discharge increaser should be installed directly on the pump nozzles. This produces better conversion of flow velocity and reduces hydraulic losses that might be caused by valves or elbows directly at the pump suction, and that might affect the pump efficiency.

Plan and install the suction line so that air pockets cannot form in it. A tight suction line is essential for proper operation of any pump. Air leaking into the suction line gets into the pump, reduces its capacity, and may cause it to stop pumping. A small air leak in the suction will cause trouble in any centrifugal pump.

Install a gate and a check valve on the discharge line close to the pump. Put the check valve between the pump and gate valve and the tapered increaser between the pump and check valve. The check valve protects the pump against excessive surge pressure and also against reverse rotation.

When the capacity of a centrifugal pump must be controlled by throttling, always use the discharge valve.

(2) Priming Centrifugal Pumps

No centrifugal pump of the usual type will start pumping properly until it has been satisfactorily primed. Satisfactory priming requires that all air must be removed from the pump, and that the pump be completely filled with the liquid. Never attempt to prime a centrifugal pump while it is running. It is necessary that the pump be at a standstill while it is being primed. Under no circumstances should a pump be operated without being completely primed.

(3) Direction of Rotation

A pump should never be run in reverse rotation. Since it is sometimes difficult to determine the rotation of polyphase alternating-current motors in advance of operation, it is necessary to try them out for proper rotation before connecting them with the pump.

(4) Packing

Do not have the packing too tight. Unduly tight packing increases power consumption and causes rapid wear of the shaft sleeve. When first starting, back off on the stuffing-box-gland

nuts until free leakage occurs. Then draw down uniformly on the stuffing-box-gland nuts until leakage is reduced to a few drops a minute. Never tighten the packing sufficiently to prevent all leakage. A slight leakage is required to lubricate the packing and prevent scoring of the shaft sleeve.

As leakage increases during the service of the pump to where it cannot be reduced by drawing up the gland, add another ring of packing to the stuffing box. After a further period of operation if excessive leakage again occurs, which cannot be controlled by gland pressure, then all the old packing should be removed from the stuffing box, and a new set of packing rings installed. When repacking the stuffing box, if packing rings of the exact size cut to proper length are not available and it is necessary to cut the rings from coil packing cut the required rings so that the joints are flush. When installing the rings in the stuffing box, make sure that the joints are staggered. If the stuffing box is fitted for a water seal and lantern ring, be sure that this ring is in the proper position when installing the new packing. Check the lantern-ring position with respect to the water-seal line when the packing is compressed.

(5) Wearing Rings

Wearing rings are fitted into the casing, and frequently on the impeller, at the inlet from the suction chamber, to reduce leakage from the discharge to the suction. These wearing rings have a small clearance and depend upon the liquid in the pump for lubrication. They will eventually wear, and the leakage will increase from discharge to the suction. Rate of wear of these rings depends principally upon the character of the liquid being pumped. Since the efficiency of the pump is lowered as the leakage past the rings increases, they should be replaced before they become badly worn.

(6) Pump Casing

Efficiency of a centrifugal pump is affected by many factors. The transition from energy of motion to pressure energy takes place within the casing. It, therefore, follows that a smooth transition is necessary for minimum losses. To this end the inside casing of the pump must be as smooth and regular as possible. Routine maintenance must be performed once every two years on all internal water passages, wire brushing, chipping, scraping and final polishing, followed by two coats of good quality paint is an essential for high efficiency.

MAINTENANCE OF ELECTRIC MOTOR

An electric motor is the most important type of machine used for driving rotating equipment like centrifugal pumps for reasons of costs, simplicity of operation and ease of maintenance.

The most common type of motor for centrifugal pump operation is the squirrel cage induction motor.

Compared to a gas engine with hundreds of moving parts, the induction motor has only one moving part, the rotor. Maintenance of the rotor bearings, if of the oil sleeve journal type, is the most important and the most frequent.

Another important maintenance requirement of electric motors concerns heat.

In this discussion, consider a common induction motor rated as follows:

200 H.P., 3 phase, 60 cycles, 1185 R.P.M.

The efficiency of the motor is 94 per cent.

The power input - $200 \div .94 = 212.8$ H.P.

Power losses due to the resistance in the windings and friction, etc., account for 6 per cent of the total power input or $212.8 \times .06 = 12.8$ H.P.

This power is unable to perform useful work, and is converted to heat. To illustrate how much heat is developed, if the heat losses from this motor were applied to one gallon of water at room temperature (72°F.) the water would boil in 2-1/2 minutes.

The manufacturer has designed the motor to remove this heat by providing ventilating ducts and fans, and has protected the windings against an allowable quantity of heat by use of such materials as mica and glass.

However, if dirt and dust are permitted to build up on the windings and clog ventilating passages, the machine will not be able to waste sufficient heat and the ensuing temperature rise will reduce the efficiency of the motor gradually to the point of insulation breakdown and possible machine failure.

To prevent this, the atmosphere in the pump room should be kept free from dust and the motor itself should be cleaned by an electrician once a year.

MAINTENANCE OF MOTORS

- (1) Keep dust removed. Dust insulates windings against the loss of heat thus interfering with proper cooling; a mat of dust will retain oil and moisture. On slip rings and commutators, dust causes wear and poor electrical contact. Wipe off housing and rings regularly, and blow the dust from the windings with a clean air jet (never above 40 p.s.i. pressure) or hand bellows. Keep oil cups closed to prevent access of dust to bearings.
- (2) Keep free from stray lubricating oil. When oil-soaked, the insulation is softened and liable to burn out. Good contact is impossible with dirty commutators or rings. Oil and dust deposits are removed by carefully scraping, or wiping with a solvent like carbon tetrachloride. Avoid soaking the insulation. Never lubricate oil ring reservoirs while the motor is running, as overfilling and spread of oil may follow when the motor is stopped.
- (3) Keep motor as dry as possible. If a megger test shows a low insulation resistance due to moist conditions, the motor may be dried by passing a low voltage current through the windings with the armature locked stationary. A fan to blow air through the windings aids evaporation. During long idleness, cover the motor with a tarpaulin and keep dry by the heat from a couple of light bulbs. When flooded, a motor may be reconditioned by controlled oven baking, by infra-red rays, or by a bath in hot paraffin.
- (4) Keep bearings properly lubricated according to manufacturer's recommendations. Bearings should be inspected at least weekly. Oil rings in sleeve bearings should rotate freely with the shaft.
- (5) Keep commutator or slip rings smooth. Good operating condition is indicated by a clean, polished brown colour; a bluish colour signifies overheating. If worn in grooves, re-surface by means of a commutator stone; never use emery cloth nor an emery stone. Reset brushes or renew them if more than half worn. Check brush pressure and clean brush holders if dirty.
- (6) Do not overload the motor. The resulting heat may melt soldered connections and bake the insulation. Overload protection is obtained by an overload relay or proper sized fuses.

TYPICAL CENTRIFUGAL PUMP DATASPEED OF 1200 RPMIMPELLER DIAMETER - 12 INCHES

<u>G. P. M.</u>	<u>HEAD (FT.)</u>	<u>EFFICIENCY</u>	<u>B. H. P.</u>
1000	164	47	88
*2000	160	71	113
3000	152	83	139
3500	147	86	151
*4000	140	87	163
4500	130	86	171
*5000	118	83	180
5500	100	77	180
*6000	72	66	165

CAPACITY

$$\frac{\text{New Capacity}}{\text{Old Capacity}} \text{ as } \frac{\text{New Diameter}}{\text{Old Diameter}} = \text{Therefore } \frac{X}{4000} = \frac{11.5}{12}$$

Cross Multiply and Solve for X

$$X = \frac{11.5}{12} \times 4000 = 0.957 \times 4000 = 3,830 \text{ G.P.M.}$$

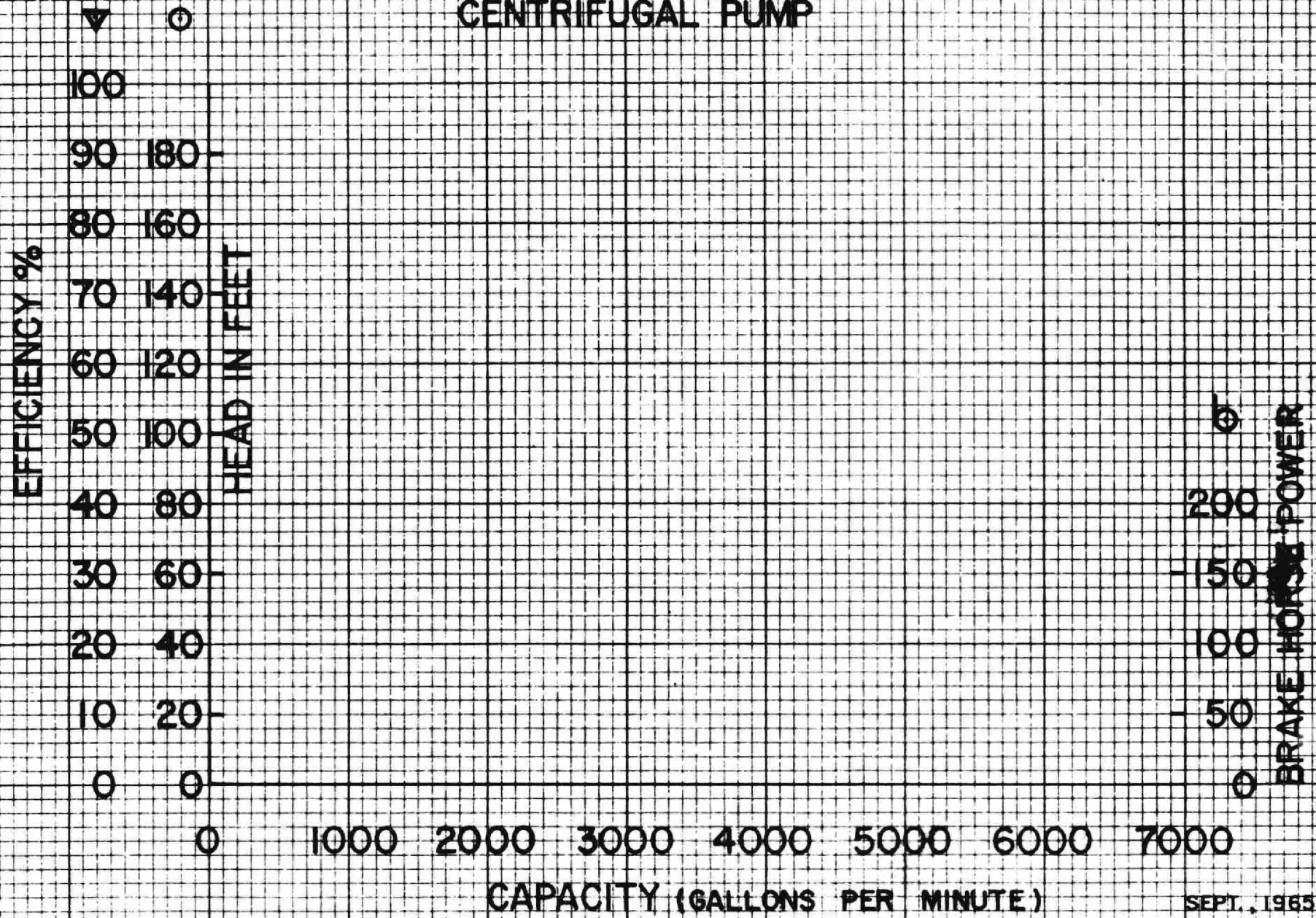
$$\text{Head } \frac{X}{140} = \left[\frac{11.5}{12} \right]^2 \text{ Therefore } X = \left[\frac{11.5}{12} \right]^2 \times 140$$

$$X = 0.916 \times 140 = 128 \text{ ft.}$$

$$\text{Power } \frac{X}{163} = \left[\frac{11.5}{12} \right]^3 \text{ Therefore } X = \left[\frac{11.5}{12} \right]^3 \times 163$$

$$X = 0.877 \times 163 = 143 \text{ H.P.}$$

CHARACTERISTIC CURVE CENTRIFUGAL PUMP



BASIC MATHEMATICS

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Division of Sanitary Engineering

This first discussion is concerned with basic mathematics. Before one can solve the problems related to dosages, pumpages, retention times, flow rates etc., he must be able to understand certain fundamental mathematics. This discussion will deal briefly with simple mathematics and with certain rules and concepts, which if used will make mathematics easier to understand and to perform.

Mathematics is the science of calculation of quantities and is used to describe as a group the three basic sciences - arithmetic, algebra and geometry.

Arithmetic is the study of numbers and the use of numbers to count, describe and calculate quantities. It includes the simple mechanical process of addition, subtraction, multiplication and division.

Geometry is the study of the magnitudes of space, such as lines, surfaces and planes.

Algebra uses symbols and equations to describe the relation between quantities and to determine solutions to problems.

ARITHMETIC

Arithmetic will be discussed under the following headings:

- addition
- subtraction
- multiplication
- division
- fractions
- decimals
- percent

Addition

Probably the only rule to remember in adding numbers which do not have the same number of digits is to line them up starting from the right-hand side.

The symbol for adding is +

Example:

Add 6,404; 28; 732

$$\begin{array}{r} 6,404 \\ 28 \\ 732 \\ \hline 7,164 \end{array}$$

Subtraction

The same basic rules which apply to addition apply to subtraction.

The symbol for subtraction is -

Example:

Subtract 828 from 4,272

$$\begin{array}{r} 4,272 \\ - 828 \\ \hline 3,444 \end{array}$$

Multiplication

Multiplication is the process of repeating or adding a given number a certain number of times. The number which is being multiplied is called the multiplicand; the number by which it is multiplied is called the multiplier; and the result is termed the product.

The symbol for multiplication is x

Example:

Multiply 6,785 by 14

$$\begin{array}{r}
 6,785 \text{ (multiplicand)} \\
 \times 14 \text{ (multiplier)} \\
 \hline
 27140 \\
 6785 \\
 \hline
 94990 \text{ (product)}
 \end{array}$$

Division

Division is simply the process of finding how many times one number or quantity is contained in another. The number which is being divided is called the dividend; the number which it is divided by is called the divisor; and the resultant number is the quotient. Quite often there is also a remainder.

The symbol for division is \div

Example:

Divide 1,752 by 12

$$\begin{array}{r}
 146 \\
 12 \overline{) 1752} \\
 \underline{12} \\
 55 \\
 \underline{48} \\
 72 \\
 \underline{72} \\
 0 \text{ - no remainder}
 \end{array}$$

Divide 18,473 by 68

$$\begin{array}{r}
 271 \text{ (quotient)} \\
 \text{(divisor) } 68 \overline{) 18473} \text{ (dividend)} \\
 \underline{136} \\
 487 \\
 \underline{476} \\
 113 \\
 \underline{68} \\
 45 \text{ (remainder)}
 \end{array}$$

Fractions

In many cases it is impossible to express a quantity as a whole number, and we must use fractional numbers such as $1/8$, $1/4$, $2/3$ etc. Difficulty is often experienced in doing minor calculations with fractions. A brief review of the calculations involved in the addition, subtraction, multiplication and division of fractions is presented.

The upper number in a fraction is called the numerator, the lower is called the denominator.

(1) Adding Fractions

Before fractions may be added they must all have a common denominator. To get a common denominator, find the smallest number into which all of the denominators will divide. Having obtained this number, multiply the numerator and denominator of each fraction by the number of times its denominator divides into the common denominator.

Fractions should always be reduced to their simplest form.

Example:

Add $\frac{3}{8}$, $\frac{1}{4}$ and $\frac{5}{16}$

By inspection the lowest number into which each of the denominators will divide is 16, and this is the common denominator. Now 8 will divide into 16 twice, and multiplying the numerator and denominator by 2, the fraction now becomes $6/16$. Similarly, $1/4$ becomes $4/16$ and we can now add because they all have a common denominator.

$$\frac{6}{16} + \frac{4}{16} + \frac{5}{16} = \frac{15}{16}$$

Often a whole number will contain a fraction, and before calculations may be made the number should be changed to a fraction only.

Example:

Add $\frac{1}{8}$ and $5 \frac{3}{4}$

The number $5 \frac{3}{4}$ is changed to a fraction by multiplying the denominator by the whole-number portion and adding the numerator, that is, 4 times 5 plus 3, and the number becomes $\frac{23}{4}$.

We now have:

$$\frac{1}{8} + \frac{23}{4}$$

Changing to a common denominator of 8:

$$\frac{1}{8} + \frac{46}{8} = \frac{47}{8} \text{ or } 5 \frac{7}{8}$$

(2) Subtracting Fractions

The rules for subtracting fractions are similar to those for adding - there must be a common denominator.

Example:

Subtract $\frac{3}{16}$ from $\frac{8}{32}$

$$\frac{8}{32} - \frac{3}{16}$$

$$= \frac{8}{32} - \frac{6}{32} = \frac{2}{32} \text{ or } \frac{1}{16}$$

(3) Multiplying Fractions

It is not necessary to change simple fractions to a common denominator before multiplying. Simply multiply the two numerators and the two denominators together.

Example:

Multiply $\frac{3}{4}$ by $\frac{2}{3}$

$$\frac{3}{4} \times \frac{2}{3}$$

$$= \frac{3 \times 2}{4 \times 3} = \frac{6}{12} \text{ or } \frac{1}{2}$$

When one of the numbers to be multiplied contains a whole number and a fraction it must be changed to a simple fraction before multiplying.

Example:

Multiply $\frac{1}{4}$ by $3 \frac{5}{8}$

$$\frac{1}{4} \times 3 \frac{5}{8}$$

$$= \frac{1}{4} \times \frac{29}{8}$$

$$= \frac{1}{4} \times \frac{29}{8} = \frac{29}{32}$$

(4) Dividing Fractions

To divide one fraction by another the simplest rule to follow is to invert the bottom fraction and multiply.

Example:

Divide $\frac{5}{16}$ by $\frac{3}{4}$

$$= \frac{5}{16} \div \frac{3}{4}$$

$$= \frac{5/16}{3/4}$$

$$= \frac{5}{16} \times \frac{4}{3}$$

$$= \frac{5 \times 4}{16 \times 3} = \frac{20}{48} = \frac{5}{12}$$

Example:Divide $5 \frac{3}{4}$ by $\frac{1}{8}$

$$5 \frac{3}{4} \div \frac{1}{8}$$

$$= \frac{5 \frac{3}{4}}{1/8}$$

$$= \frac{23/4}{1/8}$$

$$= \frac{23}{4} \times \frac{8}{1}$$

$$= \frac{184}{4} = \frac{46}{1} = 46$$

Decimals

Another method of expressing fractional numbers is by the use of decimals. Decimals express fractions in multiples of 10, that is, tenths, hundredths and thousandths.

$$\frac{1}{10} = 0.1 \quad \frac{1}{100} = 0.01 \quad \frac{1}{1000} = 0.001$$

As shown above, a decimal fraction is denoted by a digit with a period in front of it. The value of the decimal depends on the position of the figures with respect to the decimal point. For example, if a decimal is immediately in front of a number it means that the number has been divided by 10.

Example:

$$0.7 = \frac{7}{10}$$

If there is a zero between the number and the decimal it means that the number has been divided by 100.

Example:

$$0.09 = \frac{9}{100}$$

In addition to decimal fractions there are also mixed decimals which are whole numbers with a decimal fraction.

Example:

$$12 \frac{1}{2} = 12.5$$

(1) Adding Decimals

When adding decimals the numbers must be listed one below the other with the decimal points in a vertical line.

Example:

Add 31.56, 4.32 and 88.8

$$\begin{array}{r} 31.56 \\ 4.32 \\ 88.80 \\ \hline 124.68 \end{array}$$

(2) Subtracting Decimals

The rules for subtracting decimals are similar to those for adding.

Example:

Subtract 8.4 from 14.73

$$\begin{array}{r} 14.73 \\ - 8.40 \\ \hline 6.33 \end{array}$$

Example:

Subtract 9.32 from 17.8

$$\begin{array}{r} 17.80 \\ - 9.32 \\ \hline 8.48 \end{array}$$

(3) Multiplying Decimals

This is done in the same way as ordinary multiplying and the decimal point is disregarded during the calculation. Add the total number of digits to the right of the decimal in the two numbers being multiplied and insert the decimal point in the answer.

Example:

Multiply 3.55 by 3.2

$$\begin{array}{r}
 3.55 \\
 \times 3.2 \\
 \hline
 710 \\
 1065 \\
 \hline
 11360 \text{ or } 11.360
 \end{array}$$

Since there are a total of three digits to the right of the decimal in the two numbers multiplied, there must be three digits to the right of the decimal in the answer.

(4) Dividing Decimals

Before dividing numbers which contain decimals the decimal in the divisor should be moved a sufficient number of digits to the right to change it to a whole number. Of course, the decimal in the dividend must also be moved a similar number of digits to the right.

Example:

Divide 253.5104 by 3.52

3.52/253.5104 becomes

$$\begin{array}{r}
 72.02 \\
 352 \overline{) 25351.04} \\
 \underline{2464} \\
 711 \\
 \underline{704} \\
 704 \\
 \underline{704} \\
 0
 \end{array}$$

The decimal point in the answer (quotient) is placed directly above the decimal point in the dividend.

To change a fraction to a decimal simply divide the numerator by the denominator.

Example:

Change $1/4$ to a decimal

$$\begin{array}{r} 0.25 \\ 4 \overline{) 1.00} \\ \underline{8} \\ 20 \\ \underline{20} \\ 0 \end{array}$$

Therefore $1/4 = 0.25$

Percent

Percent is a proportion expressed in hundredths and is used to provide a comparison of the whole. For example, one percent represents $1/100$ part of the whole.

Example:

A student obtains 75 marks on a test out of a total of 100. What was his percent?

$$\frac{75}{100} \times 100 = 75 \text{ percent}$$

ALGEBRA

Although the water works operator will not be called upon too often to use algebra, a little understanding of the subject will be helpful.

Equations

The most commonly encountered item in algebra is the equation, which is simply a statement of equality of two quantities.

Examples:

$$\begin{aligned}
 2 + 2 &= 4 \\
 7 - 4 &= 3 \\
 a + b &= c \\
 2x &= 10 \text{ etc.}
 \end{aligned}$$

As long as the same changes are made to both sides of the equation it will remain unchanged. That is, any amount may be added to or subtracted from both sides, or both sides may be multiplied or divided by the same number, and the equation will remain the same.

Example:

If $3a$ equals 24, what does a equal?

$$3a = 24$$

Dividing both sides of the equation by 3

$$\frac{3a}{3} = \frac{24}{3}$$

$$a = 8$$

Example:

If $\frac{b}{5} = 3$, what does b equal?

$$5 \times \frac{b}{5} = 3 \times 5$$

$$b = 15$$

Ratio and Proportion

A ratio is a comparison. For example, if one car costs \$6,000 and a second car costs \$2,000, we say that the first car is 3 times as expensive as the second. Expressed mathematically the ratio is 3:1 and the value of the ratio is 3.

A proportion is simply a statement of equality between two ratios. In the case of the two cars the proportion is

$$\frac{6,000}{2,000} = \frac{3}{1} \text{ or } 6,000:2,000 = 3:1$$

In practice, numerous problems are encountered in which one ratio is known and we must find an equal ratio of which only one of the items is known.

Example:

A desk is 6 ft. long and 3 ft. wide. A desk of similar shape is required with one side 8 ft. long. What will the width be?

$$\text{desk one } \frac{L}{W} = \frac{6}{3} = 2$$

$$\text{desk two } \frac{8}{W} = 2$$

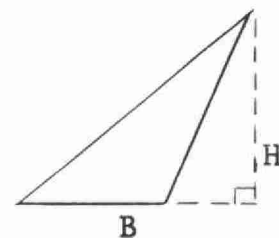
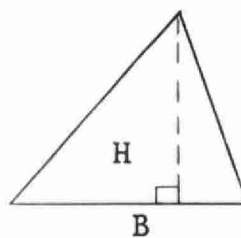
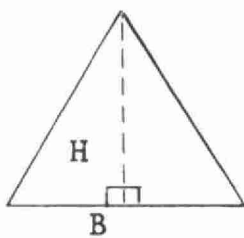
$$\text{Therefore } W = 4$$

GEOMETRY

A water works operator is often called upon to figure out areas and volumes. The types of figures which he is most likely to encounter are shown below:

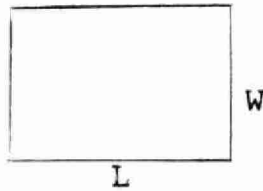
Areas

(1) Triangle



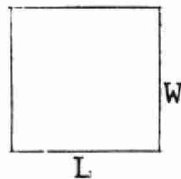
The area of a triangle:

$$\begin{aligned} A &= \frac{1}{2} \text{ base } \times \text{ height} \\ &= \frac{1}{2} B \times H \end{aligned}$$

(2) Rectangle

The area of a rectangle:

$$A = L \times W$$

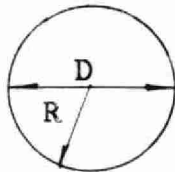
(3) Square

The area of a square:

$$A = L \times W$$

but $L = W$

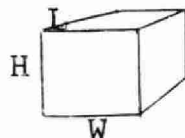
$$\text{Therefore } A = L^2$$

(4) Circle

The area of a circle:

$$A = \pi R^2 \quad \text{or} \quad \frac{\pi D^2}{4}$$

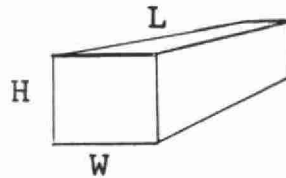
D = diameter
 R = radius = $1/2D$
 C = circumference
 $\pi = 3.14$

Volumes(1) Cube

The volume of a cube:

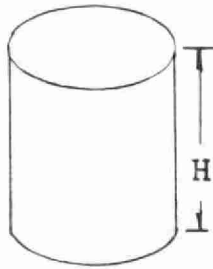
$$V = L \times W \times H = L^3$$

all three sides equal
 $L = W = H$

(2) Rectangular Solid

The volume of a rectangular solid:

$$V = L \times W \times H$$

(3) Cylinder

The volume of a cylinder:

$$V = \frac{\pi D^2}{4} \times H$$

TABLE IBRITISH SYSTEMLinear Measure

1 foot = 12 inches
 1 yard = 3 feet
 1 rod = 5 1/2 yards
 1 mile = 1,760 yards
 1 mile = 5,280 feet

Square Measure

1 square foot = 144 square inches
 1 square yard = 9 square feet
 1 acre = 160 square rods
 1 square mile = 640 acres
 1 acre = 43,560 square feet

Cubic Measure

1 cubic foot = 1,728 cubic inches
 1 cubic yard = 27 cubic feet

Weight

1 pound = 16 ounces
 1 ton = 2,000 pounds
 1 pound = 7,000 grains

Liquid Measure

1 quart = 2 pints
 1 gallon = 4 quarts

METRIC SYSTEMLinear Measure

1 centimeter = 10 millimeters
 1 meter = 100 centimeters
 1 kilometer = 1,000 meters

Square Measure

1 sq. centimeter = 100 sq. mm
 1 sq. meter = 1,000 sq. centimeter
 1 sq. kilometer = 1,000,000 sq. meters

Cubic Measure

1 cubic centimeter = 1,000 cu. mm
 1 cubic meter = 1,000 litres

Metric Weight

1 gram = 1,000 milligrams
 1 kilogram = 1,000 grams

CHLORINE RESIDUALS - TIME & TEMPERATURE EFFECTS

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Disinfection of the water supply is not the only reason for chlorination. Ammonia, sulphide, phenols, iron and proteins are just a few of many chemical nuisance factors treatable by chlorination. However, excessive chlorination can make these problems worse.

CAREFUL CONTROL IS REQUIRED

When chlorite or hypochlorite is added to water, either as a solid or in a solution such as "Javex", the resulting dilution with water causes these chemicals to break down to form free chlorine gas and/or hypochlorous acid and/or chlorite ion. All these chemicals react as if they were Free Available Chlorine. They will react with other materials in the water to form Combined Available Chlorine such as chloramines which, under suitable conditions, will slowly release chlorine back to the water. In addition, some chlorine will react to produce chloride ion. (Recall that common house salt is sodium chloride). This chloride does not release chlorine back into solution.

Orthotolidine is the reagent used for measuring chlorine residual. It is prepared as a solution which is stable for not more than six months. It should be:

- a) stored in amber bottles or in the dark
- b) protected at all times from direct sunlight
- c) kept from contact with rubber (e.g. stoppers, tubing)
- d) stored at room temperature

PROCEDURE

For precise directions refer to Standard Methods, 12th Edition, pages 90-91 and 94-100. The following points should be noted however:-

- a) Add sample to reagent (Put reagent in first)
- b) Permanent standards such as Nesslerizer Colour Disks may be used with 50 ml. nessler tubes.
- c) More than 0.3 ppm iron, 0.01 ppm manganic, and/or 0.10 ppm nitrite - N will produce extra colour (i.e. interference).
- d) Make colour comparisons against a standard artificial light.
- e) Avoid direct sunlight at all times during analysis to prevent fading of the developed colour.
- f) Both time and temperature affect the results.

EFFECT OF TIME AND TEMPERATURE

Most chemical reactions are not instantaneous; they require time to go to completion. In the Chlorine Residual test we make use of this fact in the following way.

Free Available Chlorine reacts almost instantly with orthotolidine to form a yellow coloured solution. After five minutes, however, this colour will start to fade due to the slow bleaching effect of sunlight.

Combined Available Chlorine, on the other hand, reacts more slowly, and at room temperature (20°C) the maximum amount of colour will have formed in about three minutes. Of course, this colour will start to fade also, after about five minutes.

In order to determine Total Available Chlorine we must allow time for the Combined Available Chlorine to react with the orthotolidine. The following table gives approximate times required for colour development at various temperatures.

<u>Combined</u> chlorine reacts in	2.5 minutes at 25°C
	3. minutes at 20°C
	6. minutes at 0°C

Free chlorine reacts instantly.

Normally, analysis is carried out at 20°C. Cold samples must be warmed to this temperature before analysis for Total Available Chlorine.

On occasion it will be necessary to have an estimate of the Free Available Chlorine content of the water. In this case we do not want the Combined Chlorine to be included. If the sample is cooled in an ice bath to 0°C, we can see from the above table that the combined chlorine will react to produce a colour, but not as quickly. Then a reading of the colour developed by the sample IMMEDIATELY after adding the sample to the orthotolidine reagent will give a good estimate of Free Available Chlorine.

Other methods of analysis for Available Chlorine are given in Standard Methods. While these may give better results when performed properly, they are not recommended for use in the plants, unless special training in the correct techniques has been given to the individual operator. The above orthotolidine method is quite suitable and will give acceptable results if the precautions mentioned above are observed.

TASTE AND ODOUR CONTROL

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The average consumer tends to associate bad tastes and unusual odours in public water supplies with poor quality water even though it may be sparkling clear and safe to drink. If the water has any adverse tastes, he will likely reject it and attempt to seek a more palatable water from another source even though the latter may not be considered desirable for human consumption.

Taste and odour control is a very important consideration in the purification of municipal water supplies especially if the waterworks operator desires to produce good quality water which will be acceptable to his consumers. This lecture shows how taste and odour problems develop and outlines briefly some of the methods of control that are being used in the production of a palatable water.

Tastes

There are only four true tastes sensations - sweet, sour, bitter and salty. All other apparent sensations which are commonly referred to as tastes are actually odours even though the sensation may not be experienced until the substance has actually been taken into the mouth.

Odours

It is almost impossible to determine and classify the different types of odours that can be experienced. Table 1 on the following page gives a qualitative description of some of the more common odours that are prevalent in water supplies. It can be used as a guide to classify the type and determine the source of odour.

Table 1

GUIDE FOR QUALITATIVE DESCRIPTIONS OF ODOURS

Code	Nature of Odour	Description (Such as Odours of:)
A	Aromatic (spicy)	camphor, cloves, lavender, lemon
Ac	cucumber	Synura
B	Balsamic (flowery)	geranium, violet, vanilla
Bg	geranium	Asterionella
Bn	nasturtium	Aphanizomenon
Bs	sweetish	Coelosphaerium
Bv	violet	Mallomonas
C	Chemical	industrial wastes or treatment chemicals
Cc	chlorinous	free chlorine
Ch	hydrocarbon	oil refinery wastes
Cm	medicinal	phenol and iodoform
Cs	sulfuretted	hydrogen sulfide
D	Disagreeable	(pronounced, unpleasant)
Df	fishy	Ureoglenopsis, Dinobryon
Dp	pigpen	Anabaena
Ds	septic	stale sewage
E	Earthy	damp earth
Ep	peaty	peat
G	Grassy	crushed grass
M	Musty	decomposing straw
Mm	moldy	damp cellar
V	Vegetable	root vegetables

Standard Method, Eleventh Edition, P. 255.

CAUSES OF TASTE AND ODOUR PROBLEMS

Taste and odour problems in water supplies are caused by the presence of certain substances which adversely affect and impair the palatability of drinking water. These can be classified into two general categories; natural causes and man-made causes. The natural causes of taste and odour problems are related to algae, decomposed organic matter and vegetation, mineral substances and hydrogen sulphide. Man-made causes are related to the odour-producing substances placed in the water as a result of pollution or other human activity. These include industrial wastes and sewage.

Algae

Algae are considered to be the most important source and the most frequent cause of objectionable tastes and odours in water. Any water supply derived from a reservoir, stream, river, lake or any other surface supply, is likely to encounter taste and odour problems associated with algae at one time or another.

Algae are simple forms of plants or plant-like organisms found in any surface water or any body of water exposed to sunlight. Many of them are microscopic in size. There are thousands of varieties of algae and many of these are responsible for taste and odour problems. Some species of algae such as Synura and Dinobryon, if present, in relatively low numbers, may cause serious odour problems while there are many others that give rise to tastes and odours varying in type and intensity according to local conditions and populations. Descriptions for some typical odours produced by algae can be found in Table 1.

Odour problems are said to be caused by oils and substances released by the algae during their life process and after death. When the algae die, their cells decay and break down to form minute quantities of soluble odour-producing materials in water. Many of these problems are experienced in the water supplies on a seasonal basis. They may occur during the late spring, early or late summer months when heavy algae blooms take place. In some instances, they may occur during the late fall or in winter when the algae begin to die.

Decaying Vegetation

Decaying vegetation is the second most important cause of tastes and odours in water supplies. This consists of any dead vegetable matter derived from living plants. It includes algae, grass, leaves, stems and any other vegetable matter which may be decomposed by various micro-organisms. During the decomposition process, many of these materials are broken down by the organisms and converted into soluble substances which impart unpleasant tastes and odours to the water.

One of the most well-known of these organisms are Actinomycetes. They are usually found in rotting plants, trees and compost piles. They produce a substance with a very strong, pungent earthy smell. When present in water at very low concentration, this material has a significant effect on its odour quality.

Aquatic Weeds

Certain types of aquatic plants may have a significant effect on the tastes and odours of the water. In areas where they grow in abundance, the water develops a distinct flavour or odour that is characteristic of the plant.

Chemical Quality

The presence of certain dissolved minerals and gases in the water may have a considerable influence on its palatability. Dissolved mineral salts, depending on concentration and type, will affect its taste. Others such as iron and sulphur compounds give rise to the growths of nuisance organisms that may cause taste and odour problems in water supplies.

Water supplies derived from wells have dissolved gases which affect the tastes and odour quality. This includes carbon dioxide, hydrogen sulphide and methane gas. The most troublesome of these is hydrogen sulphide because of its ability to impart objectionable odours to the water if present in quantities less than one ppm. Waters with carbon dioxide usually have stale tastes. Similarly, waters with methane and other natural gases give off characteristic odours.

Industrial Wastes

Taste and odour problems may be expected in water supplies drawn from lakes and streams receiving wastes discharges from certain types of industries. Among the industrial wastes that can produce troublesome problems in water supplies include those from organic chemical plants, oil refineries, food processing and beverage plants, paper mills, tanneries, meat packing houses, by-product coke plants and plastic manufacturing plants.

Many of these wastes contain substances such as phenols and pyridine which cause undesirable tastes in potable waters at very low concentrations. Others may contain substances which decompose and produce highly malodorous substances which impart septic or foul odours. Some wastes may even have compounds which react with chlorine to form obnoxious odour-producing substances such as chlorophenols and other chlorinated organics. Still, others containing large amounts of salts and bitter-tasting substances may seriously affect the true taste of the water.

Sewage

Domestic sewage contains certain types of substances that may seriously affect the palatability of water if contaminated. One notable example of these is the synthetic detergent. The latter has gained a wide acceptance by the consumers in recent years. Many of the synthetic detergents are formulated from complex organic compounds which, if chlorinated, may produce strong odour-causing substances. Others are capable of producing soapy tastes.

Nuisance Organisms

There are a number of different micro-organisms that may flourish in the distribution system under suitable conditions of water quality. If unchecked, they may develop serious taste and odour problems. They are referred to as nuisance organisms and they include:

- (a) iron bacteria
- (b) sulphur bacteria
- (c) sulphate-reducing bacteria
- (d) slime growths.

Iron bacteria are usually found in water with slime deposits on the walls of water pipes and tanks and cause unsightly discolorations in the water. Eventually the slime growths decompose and form substances which can lead to undesirable taste and odour conditions in the distribution system.

Sulphur bacteria are capable of decomposing proteins or sulphur-containing substances and converting them into either elemental sulphur or sulphates. Under anaerobic conditions sulphate-reducing bacteria can reduce sulphates into hydrogen sulphide.

Slime growths appear on the walls of open channels, settling basins, filter beds, reservoirs and in many parts of the distribution system. They are unsightly in appearance. Upon decomposition, they may produce substances that adversely affect the taste and odour quality of water.

Water Treatment Practice

There are at least two areas in the waterworks, if overlooked, may lead to serious taste and odour problems in the water supply. One of these involves the settling basin where all of the impurities from the water are removed during the water purification process and collected as a sludge. If the sludge is allowed to accumulate and remain for any length of time, it will decompose and form odorous substances that may seriously affect the palatability of water.

The second area that may arouse some consumer complaints is related to the improper use of chemicals in the treatment process, notably chlorine and others employed in taste and odour control. There is no doubt that natural odours in the water may be intensified or changed in character by chlorination. Chlorine, if applied in excess, is not desirable as it will produce highly objectionable tastes in the water. The presence of unreacted chemicals in the drinking water resulting from improper application may also affect the tastes and odours. For example, unreacted sodium chlorite derived from the chlorine dioxide treatment.

CONTROL METHODS

There are two general methods employed in solving taste and odour problems in municipal water supplies - preventive treatment and corrective treatment. Preventive treatment involves the various measures that are taken to remove the source of these problems and to control the conditions so that these problems do not develop. It consists of action taken to control growths of algae, aquatic plants and nuisance organisms in the water supply. Corrective treatment involves the action that must be taken to correct these problems after they have developed in the water supply. It is usually applied in conjunction with the treatment process for the specific purpose of lessening the taste and odour conditions in the water.

Preventive Treatment

- (a) Control of Aquatic Plants in Impounded Areas
and Reservoirs
 - (i) Periodic cleaning
 - (ii) Use of chemicals
- (b) Control of Algae Growths in Open Bodies of Water
 - (i) Elimination of Sunlight by covering or use of carbon "blackout"
 - (ii) Application of chemicals such as copper sulphate and algicides
- (c) Control of Nuisance Organisms in Distribution
Systems
 - (i) Proper disinfection practices
 - (ii) Periodic flushing out of watermains
- (d) Good Housekeeping Practices
- (e) Proper Control of Chemical Applications

Corrective Treatment

Corrective treatment consists of removing the taste- and odour-causing substances in the water or changing their

chemical characteristics so that they will no longer react with chlorine to produce offensive odours. It may involve physical and/or chemical methods.

Physical methods are designed to remove these substances physically from the water and may involve one of the following:

- (a) coagulation and filtration
- (b) volatilization
- (c) adsorption

Chemical methods involve the use of chemicals to oxidize or decompose substances or to change its character in such a way that it will not cause any taste and odour problems in water. Each of these treatment methods will be discussed briefly.

Coagulation and Filtration

Coagulation and filtration are part of the water treatment process. Chemical coagulation itself has very little effect on the removal of tastes and odours unless they are associated with colour and turbidity. Filtration is effective in removing any floating or suspended particles that may contribute to the taste and odour problems. However, if these conditions are severe or caused by soluble materials, these methods have very limited effect on taste and odour control. Additional methods of treatment must be provided.

Volatilization by Aeration

Volatilization consists of removing volatile substances such as dissolved gases from water by means of aeration.

The purpose of aeration is to bring water into intimate contact with air by the use of aerators, sprayers, trickling devices and other aeration equipment. Upon exposure to air, odorous substances such as hydrogen sulphide and dissolved gases are removed from the water and volatilized into the atmosphere.

Aeration was one of earlier methods of treatment used for odours in municipal water supplies. It was found to be very effective in waters containing easily oxidizable or volatile gases such as carbon dioxide and hydrogen sulphide. However, its usefulness for the complete removal of tastes and odours in water supplies is limited because most of the dissolved substances cannot be oxidized nor removed by aeration alone.

ADSORPTION WITH ACTIVATED CARBON

The use of activated carbon is the most widely known method employed in controlling tastes and odours in water treatment. It has the ability to remove all types of organic substances and gases that may be present in water. The surface of the carbon particle possesses an attractive force that enables it to draw and hold on to the molecules of other substances that come into contact with it. This ability of the activated carbon to attract and hold other substances is known as "adsorption".

All of the tastes and odours in water can be removed completely if enough carbon is added in the proper place. For the purification of potable water supplies, activated carbon in the powdered form is considered to be the most economical and most efficient method of treatment. Powdered carbon can be used only in water treatment plants that are equipped with filters which can take it out from the water before distribution to the consumer.

The efficiency of taste and odour removal utilizing powdered activated carbon is dependent on the following conditions:

- (a) good mixing facilities
- (b) adequate dosage
- (c) point of application
- (d) time of contact

All of these points will be dealt with in a later lecture.

Granular Activated Carbon Filters

The use of granular activated carbon filters has become increasingly popular within recent years for purification of municipal water supplies. This method of treatment has been found to be very effective and reliable in removing a wide range of organic contaminants such as detergents, insecticides, industrial pollutants and any taste- and odour- causing substances. It has been used extensively in Europe, particularly in Germany for many years for the removal of odorous organic contaminants and also as a method of dechlorination. However, in Canada and United States, granular activated carbon filters have not been utilized in the treatment of municipal water supplies because it was found that this could be done more economically with powdered carbon.

At the present time, granular carbon filters are used most in bottling plants and food industries where the consistency in taste and odour quality of water is very important. However, with the development of new technology, these filters will likely be adopted for the purification of municipal water supplies. Recent studies have shown that if the spent granular carbon can be reactivated and used over and over again, this method of treatment would be economically feasible for large waterworks.

Chemical Treatment

For the control and removal of unpleasant tastes and odours in municipal water supplies, oxidizing chemicals or oxidants are usually employed. With proper usage, they react and destroy the odour-causing substances in water and convert them into non-odorous compounds. Any one of the following chemicals may be used for this purpose: (a) chlorine, (b) chlorine dioxide, (c) potassium permanganate and (d) ozone.

Chlorination

Chlorine is a relatively effective method for taste and odour control provided that it is properly applied. Of all of the oxidizing chemicals utilized in water treatment, it is best known and most widely used for this purpose because of the following reasons:

(a) it destroys and controls the growths of algae and nuisance organisms in the water supply.

(b) it destroys odour-causing organic substances.

(c) it destroys hydrogen sulphide in water very effectively.

(d) it prevents septic conditions from developing in the distribution system.

Advantages

(a) Chlorine is readily available at most waterworks plants and therefore the purchase of special feed equipment is not necessary.

(b) Chlorine is relatively inexpensive in comparison to other chemicals.

(c) Increased dosage of chlorine for taste and odour control provides better disinfection of water.

(d) Chemical dosage of chlorine can be very easily controlled and maintained on a continuous basis.

Disadvantages

(a) Proper control must be maintained at all times as excess chlorine in water may cause objectionable tastes.

(b) Chlorine may actually intensify odours emitted by certain organic compounds, e. g. phenols and phenolics.

Free Residual or Break-point Chlorination

Chlorine is a powerful oxidizing chemical. It will react with many substances that are dissolved or suspended in the water. Unfortunately, in reactions with some substances such as phenols, it produces chlorine compounds that are

highly odorous. If higher dosages are added, chlorine will destroy many of these derivatives including those from reactions with ammonia and other nitrogen compounds. For example, with sufficient dosage, chlorine will completely oxidize hydrogen sulphide so that it is no longer obnoxious.

When chlorine reacts with any substance present in water, it loses its oxidizing power and hence it is no longer available as a disinfecting agent. However, if enough chlorine is applied to react with all of the substances in the water and completely oxidize ammonia and other organic compounds, the chlorine demand is said to be satisfied. Any additional chlorine applied to the water will show as free available chlorine residual.

Free residual or breakpoint chlorination is a technique which involves the application of chlorine to water to satisfy the chlorine demand in order to obtain free available chlorine in the water. It can be used very effectively for taste and odour control.

Advantages

(a) It is a simple method of treatment which can be implemented in most waterworks without installation of any elaborate chemical feeders.

(b) It is a more effective method of disinfection.

(c) Free available chlorine residual is more persistent and will remain in the distribution system over a longer period of time.

(d) With proper application, some of the taste- and odour-causing substances in the water can be removed or destroyed.

Disadvantages

(a) Proper control must be maintained at all times to avoid chlorinous tastes associated with excess dosages.

(b) Chlorine demand may fluctuate from time to time due to changes in the raw water quality.

(c) This method is not always effective in combatting problems caused by certain organic compounds, e.g. phenols.

Superchlorination and Dechlorination

Superchlorination is another variation of free residual chlorination. It involves the application of chlorine in excess without any regard to the amount of chlorine residual produced in water. After treatment, the water contains a very high level of chlorine residual which may impart undesirable tastes. Therefore, it is necessary to dechlorinate or reduce the excess chlorine by the application of one of several dechlorinating agents. These include ammonia, sodium sulphite, sodium thiosulphate and sulphur dioxide. Sulphur dioxide is considered to be the least expensive chemical for this purpose. Granular activated carbon filter is also used for removing excess chlorine.

Super-chlorination is utilized for taste and odour control at waterworks where the raw water quality is subjected to fluctuations.

Advantages

(a) It ensures proper treatment in water supplies with widely fluctuating raw water quality.

(b) It is effective in plants with short detention periods.

(c) High chlorine dosages will enable complete destruction of micro-organisms and odouring causing substances.

Disadvantages

(a) Additional equipment is required to apply dechlorinating agent.

(b) Large amounts of chemicals are consumed in the treatment.

Ammonia-Chlorine Treatment (Chloramination)

Chloramination (chloramine) treatment is another method for lessening any taste and odour problems developed by chlorination. The chlorine, when added, reacts with the applied or natural ammonia in the water to form chloramines.

Ammonia helps to retard the oxidizing power of chlorine and prevents the formulation of odoriferous chlorinated organic compounds. Because of this, objectionable tastes and odours are not likely to develop as rapidly in waters subjected to chloramine treatment.

Chloramines have been particularly effective in minimizing the development of severe tastes in waters containing phenols. They can also insure the maintenance of a chlorine residual over a longer period of time in the distribution system.

For taste and odour control, the ammonia is added to the water first and mixed thoroughly before the application of chlorine. This prevents the chlorine from combining with organic substances to form any odour-producing compounds. In practice, the chemicals are usually applied in the weight ratio of five parts of chlorine to each part of ammonia.

Advantages

- (a) It suppresses the development of chlorophenolic tastes.
- (b) Higher chlorine residuals can be applied without any adverse effects.
- (c) Chlorine residuals can be sustained in the distribution system for a longer period.

Disadvantages

- (a) It is the least effective method of chlorination for eliminating taste and odour problems.
- (b) Excess ammonia may encourage growths of organisms in the system.

Chlorine Dioxide

Chlorine Dioxide is a powerful oxidizing agent having 2½ times greater oxidizing capacity than chlorine. It has been used very successfully in controlling taste and odour problems in water supplies contaminated with phenolic and other industrial pollutants.

Chlorine dioxide is a very unstable yellowish red gas which must be produced as it is needed. It cannot be shipped or stored in bulk. It is generated at the waterworks by one of the following reactions:

- (a) sodium chlorite and chlorine,
- (b) sodium chlorite and acidified calcium or sodium hypochlorite.

Theoretically, one part of chlorine reacts with 2.1 parts of sodium chlorite (80% NaClO₂) but in practice, the feed ratio of chlorine to sodium chlorite is maintained at not less than 1:2 and more preferably 1:1.

Advantages

- (a) It is most effective against taste and odour problems due to chlorophenols.
- (b) It has some disinfecting value.

Disadvantages

- (a) Sodium chlorite is relatively expensive.
- (b) Careful control required in maintaining proper ratio of chlorine to sodium chlorite.
- (c) With the exception to chlorophenolic tastes, there are some doubts about its effectiveness against other types of taste and odour problems.

Ozonization

Ozonization (ozonation) is another method of water purification that has been used extensively in Europe and in the British Isles for disinfection of water supplies and in some parts of the United States for taste and odour control.

Ozone is a faint bluish gas with a pungent odour. It is produced in a special electrical apparatus known as an ozonator by discharging a high voltage electrical current through dry air. During the process, some part of the atmospheric oxygen (O_2) is converted into ozone (O_3).

Chemically, ozone is one of the most powerful oxidizing agents. It is unstable and is ready to combine vigorously with any oxidizable substance either in the air or water.

Advantages

- (a) It has a very rapid sterilizing effect on water.
- (b) In some cases, it can improve the colour of the water while removing its tastes and odours.
- (c) There is no danger of overtreatment.
- (d) By-products resulting from ozone treatment are not known to cause taste and odour problems.

Disadvantages

- (a) Cost of equipment for producing ozone is very expensive.
- (b) Only limited data are available and they have indicated that ozone is not entirely satisfactory.

Potassium Permanganate

Potassium permanganate has been introduced recently for the taste and odour control of municipal water supplies. It is a dark greyish crystalline powder which dissolves in water producing a dark purple solution. It is a strong oxidizing agent that will oxidize and break down troublesome organic substances into harmless compounds that will not produce any taste- and odour-causing by-products when subjected to chlorination.

Two basic requirements in a waterworks must be met before the use of potassium permanganate can be considered.

- (a) good filtration system,
- (b) adequate detention time prior to filtration.

Upon reaction with oxidizable materials, the potassium permanganate is reduced and forms an insoluble brown precipitate. If left in the water, the latter will cause unsightly discoloration and therefore must be removed by means of filtration.

Advantages

- (a) It is a chemical that can be stored and handled with relative ease.
- (b) Only very low dosages of chemical are required in most instances.
- (c) Its precipitate acts as a coagulant aid and improves coagulation.
- (d) It has some disinfecting powers.
- (e) It removes iron and manganese compounds that affect the tastes of water.

Disadvantages

- (a) For best results, the plant must have good coagulation and filtration facilities.

(b) proper control must be maintained to avoid penetration of filters by unreacted chemical.

(c) improper use may lead to unsightly discoloration of the treated water.

SUMMARY

Taste and odour control in water purification is a very important factor because the waterwork operator must deliver to his consumers water of good palatability and consistency in taste.

Not all of these methods can be made applicable to all taste and odour problems and no one method will be suited to all waterworks. Each operator must study his own problem, consider the equipment and facilities he has available and then decide on the treatment which would provide the best results.

Review Questions

1. List possible causes of taste and odour problems in water supplies.

2. If the water in your waterworks was affected by these problems, what method of treatment would you consider?

3. Is chlorination considered to be a good method for controlling taste and odour conditions in water supplies? Give your reasons.

GROUND WATER SUPPLIES

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INTRODUCTION

Water can be considered as one of the most important natural resources of this province. In this discussion, we will deal mainly with that water which occurs in the saturated portions of the overburden and the rock. This water is called ground water. Because we cannot see ground water under normal conditions, we often assume that it is present in limited quantities and as such is not a satisfactory water supply; however, ground water is an important source of supply throughout the world and its use for home, farm, municipal, industrial, and irrigational supplies continues to increase. It is estimated that at the present time, over 30 percent of the total water used in Ontario is ground water.

SOURCE AND MOVEMENT

Ground water is part of the hydrologic cycle. This cycle has been called the circulatory system of the earth. Moisture-laden air moving over the land masses from the oceans drops about 30 inches of precipitation in the form of rain and snow on North America every year. Of this amount, 60 to 80 percent is returned to the atmosphere by direct evaporation as it falls, by evaporation from the land surface, by evaporation from bodies of surface water, by evaporation from vegetation, and by transpiration from the plants which draw water up from the soil through their roots. Of the remaining portion, 10 to 20 percent reaches surface-water bodies directly as surface runoff. Some of the remainder infiltrates into the ground to form the soil moisture which is available to vegetation and a very small amount, probably about 10 to 20 percent, moves downward to become ground water in the saturated zone.

Water in the saturated zone moves under the influence of gravity at rates of from about five feet per day to about five feet per year, until it reappears at surface as a spring or discharge into a stream, lake, or ocean. This fact is readily recognized when we observe rivers and streams continuing to flow after long periods of no rainfall. The rivers are being fed by ground water which drains slowly into the river channels throughout the drainage system. Only during the more intense or long rainfall periods do appreciable quantities of precipitation run off directly to streams without passing through the ground. It is very important to keep in mind that ground water and surface water are not separate and distinct but closely interrelated.

STORAGE

It can be seen that as part of the hydrologic cycle, ground water is a renewable natural resource and the amount that finally flows out on surface or is extracted by means of wells is usually replaced every year. If we assume that about 20 percent of the precipitation that reaches the earth's surface infiltrates into the ground, this would mean that for every square mile of land surface .25 million gallons of water per day would infiltrate. This figure, however, is controlled by such factors as topography, soil type, vegetal cover, and geological conditions. Where sand and gravel deposits are present at surface or where bedrock formations with their weathered surfaces outcrop, a maximum amount of infiltration will take place. On the other hand, surface deposits of clay or clay-till will contribute to a greater amount of surface runoff.

As mentioned earlier, ground water is stored in the pore spaces between the sand and clay particles and in the crevices and solution channels of the rock formations. Poorly sorted sand, gravel, silt, and clay materials, such as occur in glacial till, where large and small particles of soil are mixed together, have a smaller proportion of pore space in which water can be stored than in well-sorted materials where all the grain sizes are equal.

A general range in porosity of natural sediments and sedimentary rocks is given in Table 1.

Table 1

Materials	Porosity Percent
Sandstone	4-30
Sand, clean and uniform	30-40+
Gravel, clean and uniform	30-40+
Sand and gravel mixed	15-25
Silt and clay	
As deposited	40-90
Compacted and dewatered	20-40
Shale	1-35
Limestone	1-50

A formation may contain many pore spaces which contain a great deal of water but if the pores are small or are not connected so water can flow freely from one pore to another, the formation may yield only a small amount of water. This introduces the second very important factor used in determining how a formation will act as a source of water. It is called permeability or the ability of a formation to transmit water. A formation such as sand and gravel or creviced limestone which has many pore spaces which are sufficiently large and interconnected to allow ground water to move freely through them is called an aquifer.

Most of us know very little of the amount of water stored in these aquifers or ground-water reservoirs. The Ontario Water Resources Commission and government agencies in several other provinces, notably Alberta and Saskatchewan, are stepping up their collection of basic data and making an inventory of ground-water conditions by means of geologic and hydrologic surveys. Some idea of the amount of water in storage may be obtained from a statement contained in the U.S. Department of Agriculture Year Book in 1955, --- "The ground-water reservoirs of the United States contain far more fresh water than the capacity of all the nation's reservoirs and lakes, including the Great Lakes. It has been estimated that the total usable ground water in storage is of the order of 10 years' annual precipitation or 30 years' runoff."

WATER-BEARING PROPERTIES OF ROCK FORMATIONS

The Precambrian granites and other intrusive, sedimentary, and volcanic rocks underlie 60 percent of the area of the province, chiefly in northern Ontario. As a rule, these formations are classified as poor aquifers. Wells may obtain sufficient water for average domestic needs from joints, cracks, or fracture planes near the surface of these rocks but high-capacity wells are confined almost entirely to the sand and gravel deposits in the overburden above them.

The limestones and dolomites of southern Ontario vary widely in their water-yielding properties. They often make better aquifers in the southwestern parts of the province than they do in south-central or eastern Ontario. The quality of the water is generally very hard and is often highly mineralized with sulphur compounds, particularly in the areas closest to lakes Erie and Ontario and the St. Lawrence River.

The shale formations yield only small quantities of water but the water is much softer than that from the limestone rocks. Salty water is frequently encountered at shallow penetrations of the shale formations.

A wide variety of overburden conditions is present in Ontario. Although much of the area is covered on the surface of the ground with clay or till materials, numerous deposits of sand and gravel are present to provide in most places suitable aquifers for average domestic needs. Areas where there are high-capacity wells for municipal, industrial, or irrigational purposes are necessarily more restricted.

Extraction of Ground Water

Aside from the utilization of naturally occurring springs, ground water is recovered by means of dug, bored, driven, and drilled wells. Although there are more dug wells in use today than any other type, the number of drilled, driven, and bored wells is increasing as a result of improved methods of well construction and the need for deeper wells which provide a more dependable supply of water. The dug, bored, and driven types of wells are normally the least satisfactory because they are usually the shallowest and are most easily

affected by variations in ground-water levels. These types of wells work best in areas where there is sand and gravel in the overburden. Under these conditions, the porosity and permeability of the aquifers are such that water is able to move into the well quickly to replace that which is withdrawn. Dug, bored, and driven wells in areas of tight, clayey overburden are often without water because the transmissibility of the clay is so low that water will not flow into the well readily; however, a few sandy seams in the clay will often keep the well supplied.

Often more reliable sources of water supply are available from drilled wells. Drilled wells usually extend deeper than dug wells into what are known as artesian aquifers. By this we mean that the water is coming from horizons either in the overburden or the bedrock that are confined by impervious strata or aquicludes. The water in a well drilled into an artesian aquifer rises up above the level where it was first encountered, because of the pressure behind it. If the pressure head is great enough, the well will flow. The flowing well is not an indication that the well is good but that the well head is lower than the pressure head of the water in the aquifer at that point.

Drilled wells ending in sand and gravel are sometimes developed with an artificial gravel pack to reduce the velocity of water flow into the well. This helps to keep the water free from sand and silt and the screen free from materials precipitating out of solution. Other wells drilled into sand and gravel are developed naturally with no gravel pack. The rock well requires no screen and, therefore, usually requires less maintenance and rehabilitation.

When water is pumped out of a well, the lowering of water pressure at the well site causes water in the aquifer to flow towards it. It is only natural that there will be a lowering of the water level or water pressure in the vicinity of any pumped well. This lowering forms a cone of depression which varies in size according to the rate at which the well is pumped and the permeability of the aquifer. In a water-table aquifer, that is one that is not confined, pumping will actually cause a dewatering of the aquifer itself and the cone of depression will spread very slowly. In an artesian or confined aquifer, which is the type into which many, if not most, of our municipal

drilled wells are constructed, the cone of depression is an imaginary pressure surface that spreads out rapidly. In the confined or artesian aquifer the effect of pumping can be observed several hundred or thousand feet away in a few minutes.

Pumping Test

When a well is constructed, a pumping test should be run to determine the permeability and storage coefficients of the aquifer. These coefficients indicate how fast the aquifer allows the water to move through it and how much of the water stored in the pores and crevices of the saturated formation is available for use. On the basis of the information obtained from a pumping test, it should be possible to give a fairly accurate rating to the capacity of the well. In such tests, many readings should be taken of water levels in the pumped well and preferably one or more gauge holes, particularly during the early part of the pumping test.

After a well has been put into use, the following observations should be made as regularly as possible:

- 1) Daily quantity pumped
- 2) Daily pumping level
- 3) Daily discharge pressure
- 4) Weekly static level

Unless these data have been recorded in a careful and orderly manner, it is very difficult to assess the cause of well failures and production decreases.

If production from a well drops off but the static level remains about the same, the trouble could be due to a faulty pump or plugging of the well. In case of pump trouble, an experienced pump mechanic should be consulted. If it appears that the well is being gradually plugged with iron or lime scale or with silt and sand particles, some form of chemical or mechanical treatment will be required to rehabilitate the well. Well problems and well maintenance are the subjects of a lecture in a later course and we will not take time to discuss them further here.

GROUND-WATER RECHARGE

If we consider that about 12 inches of water is available annually from precipitation for use in our streams and ground water and if we assume at least one half of this amount infiltrates into the ground to an aquifer, we have a better understanding of where the recharge comes from that replaces the water removed by pumping. An interesting fact is that the average annual recharge period extends from November to May. Most of the rain that falls during the summer and fall months never reaches the zone of saturation because it is used up mostly as soil moisture.

If the static level, or the level to which the water rises when the well is not being pumped, is gradually lowering in a well, it indicates that more water is being removed from the aquifer than is entering by natural recharge. The lowering of ground-water levels in the vicinity of pumped wells is not necessarily something to be alarmed about provided that at some time, the ever widening cone of depression finally includes sufficient recharge to balance the withdrawals. This may take place if the cone extends to intersect a body of surface water.

Just as in a surface reservoir or lake, it is perfectly feasible to draw on stored water during periods of drought with a consequent lowering of the water level, a similar withdrawal from storage from an aquifer would lower the level of the water table. The falling water tables we hear about are not unexpected during periods of low recharge; however, during wet years the storage tends to be replenished.

Water levels that continue to lower and do not show the effect of recharge indicate the mining of ground water. The continuation of such an over-draft will either lower the water level to the limit of economic lift or will exhaust the stored water.

It should be pointed out here that many aquifers can be recharged by artificial means either by means of pits or wells. The hydraulics of ground water is a very important study which increases our knowledge of the relationship of ground-water supplies to their extraction through wells. It is the subject of a lecture for a more advance course.

WATER QUALITY

Water moving through the atmosphere and the soil particles comes into contact with many soluble materials. These form chemical compounds, or salts, which are contained in solution.

Some rocks are more soluble than others. Granites and other igneous rocks are relatively insoluble but limestones, gypsum, and dolomite can be quite soluble. Over long periods of time, considerable amounts of calcium carbonate or sulphate are taken into solution from these rocks.

The hardness of water is due to the presence of bicarbonate and carbonate salts of calcium and magnesium and the alkaline-earth sulphates, chlorides etc. The former contribute to the "Carbonate" or "temporary" hardness and the latter to the "non-carbonate" or "permanent" hardness.

Ground water is usually very hard. A hardness scale in common use is as follows:

	<u>Hardness</u>
Soft water	0 - 60 ppm of Ca CO ₃
Medium or moderate hard water	61 - 120 " " " "
Hard water	121 - 180 " " " "
Very hard water	greater than 180 " "

Depending on geological conditions, ground water may also contain amounts of hydrogen sulphide, salt, or iron.

WATER USE

The principal uses of ground water are for domestic, farm, municipal, industrial, and irrigation purposes. The use of ground water has increased considerably in recent years in Ontario particularly in parts of southwestern Ontario. This has contributed to problems of water rights in common with surface-water supplies

Irrigation use is to a large degree consumptive use in that the water is lost by evaporation and transpiration and does not return to the aquifer.

Industrial, municipal, and other uses of water have also increased but their effect on water supply is not as pronounced as irrigation use as most of it is returned to either surface or ground-water sources again. Re-use of ground water is practised to a greater degree in some other countries than in Canada.

Approximately 30 percent of the people in Ontario use ground water. If we were to consider only those served by municipal water-works systems this percentage is reduced to about 17. In 1966, of 600 communities, 55 percent were served by ground water.

About 77 percent of the well supplies were untreated, about 20 percent required chlorination only and about three percent had iron removal, aeration, or softening with or without chlorination.

CONCLUSION

In conclusion, we may say that ground-water supplies in Ontario are very important to its economy. Although tremendous quantities are unused, we do not know exactly what these reserves amount to. Ground-water investigations will have to be greatly increased before this information is known.

Ground water is a renewable resource. Within limits of local precipitation and geological conditions, ground-water reservoirs can be lowered annually without endangering the supply provided the withdrawals are equal to the average perennial recharge.

Finally, although ground water is usually very hard and may contain other undesirable chemical constituents, the advantages of cool and constant temperatures along with the economy of setting up and operating the water works system usually make it the preferred source of supply if the desired quantity of water is assured.

GENERAL SAFETY PRACTICES

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INTRODUCTION

The theme which must be stressed in all safety work is that the greatest asset a water utility has is its personnel and good business dictates that this asset be protected. Thus, good utility management demands that a well co-ordinated and vigorous safety program be instituted at all water utilities. The mere lack of a safety program at a water utility would indicate that management is not alert to its duties.

A SAFETY PRACTICE PROGRAM

Before a safety program can be established, it must have the full co-operation and active support of management. It is imperative that one person in the utility organization be designated as responsible for the program. In a small water works system, that person may be the superintendent, while in larger organizations another person who can devote part or full time to the job may be so designated.

The next step in setting up the program is to provide for: (1) keeping injury records, (2) locating the hazards, (3) making equipment, plant arrangements and working methods safe, (4) getting employees interested in safety and (5) controlling work habits.

INJURY RECORDS

The keeping of injury records is basic to a safety program. With complete records, the program is given direction and is sure of success. The records should be short and contain space for all pertinent data. The forms should cover such items as: (1) accident report, (2) description of accident, (3) physician's statement, (4) corrective action taken and (5) accident analysis chart.

LOCATING THE HAZARDS

The person responsible for the safety program should constantly be on the alert for hazards which may cause an injury to an employee. One of the best methods of attacking this problem is to search the records for the conditions and situations that have produced injuries. Records such as this provide evidence of the need for a corrective program.

Many other sources of information on hazardous conditions are available. These include safety manuals, insurance company brochures, etc. These sources of information should be used freely and frequently.

EQUIPMENT, PLANT ARRANGEMENTS, WORKING METHODS

Nothing prevents accidents as effectively as the elimination of the causes. To preach safety while permitting unsafe conditions to prevail is bound to create an obstacle to the co-operation required from employees. Only when safety is integrated into the job are workers convinced that the man responsible for safety wants to prevent accidents.

CONTROLLING WORK HABITS

There are always several ways to do a job, some of which are not safe. Work methods for all routine jobs should be analyzed and standardized on one safe way. These safe ways for doing a job should be stressed upon until they are not only accepted but the methods for doing the work become habitual. Thus, safety becomes a habit.

SAFE WORK PRACTICES

The accumulated records, statistics and information become of value when used for analysis because they permit closer concentration toward accident-prevention in the most hazardous areas. A study of the causes, the types and the sources of accidents may call for closer supervision, additional training and/or education in certain fields of operation. It is in this analysis that the safety program can make its best efforts and eliminate or minimize accidents and injury.

INDOCTRINATION

The indoctrination of new employees is very important. This should be done at the time of employment, again by his supervisor and then as on-the-job training by his immediate foreman. This is the point where the employee develops the safe work habit.

ON-THE-JOB TRAINING

Since safe work practices are the responsibility of the foreman as an essential part of his job, he must see that each workman fully develops the safe work habit. On-the-job training demands that safety be a part of job planning and job performance.

PLANT LABORATORY

Essential Items Required

Adequate lighting	Marked refuse
Adequate ventilation	containers
Draft hoods	First Aid Kits
Deluge showers	
Appropriate signs & notices	
Protective clothing	

OPERATING SAFETY INSTRUCTIONS

1. Laboratory glassware must not be used for food or any other use than what was intended.
2. All bottles and containers must be clearly marked that the materials they contain can be clearly identified.
3. Suction bulbs will be used on all pipettes.
4. Access areas around shut-off valves and top areas of the sink and counter must be kept clear of unused equipment at all times.
5. Oil or grease must not be used as lubricants when making glass to hose connections on any laboratory equipment. Use only water or water soluble lubricant jellies.

6. Gloves should be worn when making glass to hose connections.
7. A thorough knowledge of first aid for dealing with accidents involving chemicals, gases, glass cuts, infections and burns of all types.
8. Bottles containing hazardous liquids must not be stored in high places where it is necessary to climb up to or reach above the head to get them. Store them in lower shelves by themselves.

VENTILATION

All areas where solvents or other compounds are used and stored must be well ventilated. The working area should be designed and constructed for the safety and convenience of the worker and for his efficient production. The ventilation should be by mechanical means with the air intake drawing air from the outside and in rooms where lime and other dry types of chemicals are used, dust accumulators should be installed in the air discharge pipe.

ALUM

Protective dustproof equipment and proper clothing should be worn by personnel handling and storing. Skin and nose irritations may be avoided by the use of plenty of water in washing and bathing.

AMMONIA

Cylinders should be stored in a cool, dry ventilated place and handled with care. Protective equipment should be available while handling and in case of leaks, only trained personnel should make repairs. First aid practices should be known to persons handling and using this material.

ACTIVATED CARBON

Storage should be in a dry fireproof space. Activated carbon should be handled with protective dustproof

equipment. Smoking must not be permitted while working with or near stored material. Plenty of water should be used in washing and bathing.

CARBON MONOXIDE

Work on engines using gas, gasoline or diesel fuel should be carried out in well ventilated areas. Improperly vented gas heaters should be corrected.

LIME

Protective dustproof equipment should be used while handling and a dust collecting system used, if possible. Storage should be in a ventilated, dry area. Plenty of water should be used in bathing and washing to prevent irritations and physicians should be consulted if irritation becomes severe.

SODA ASH

Soda ash should be handled in the same manner as described previously for lime.

SOLVENTS

Care should be taken when solvents are used in confined areas. The area should be well ventilated. Solvents should be cleaned from skin to prevent irritations.

BARRICADES AND TRAFFIC CONTROL

An adequate and safe work areamust be protected. Sufficient traffic cones and barricades should always be carried by crews assigned to construction or maintenance work in streets. Barricades should be painted bright, visible colours and maintained in good condition. Warning signs, flags, flares should always be adequate and in positions where they can be observed easily.

BUILDING MAINTENANCE

Periodic inspections are necessary to eliminate hazards (fire, safeguards, etc.) Suggested repairs for safety should receive immediate attention. Floors, hallways and stairways should always be well lighted, clean, orderly and free from oil, dirt and debris. Immediate repairs of hazardous electrical outlets and fixtures should be routine. Adequate sanitary facilities for employees must be provided. Hand rails on steps and stairways should be provided and used. Good housekeeping should be provided and used. Good housekeeping must be maintained.

FIRE PROTECTION

Good housekeeping is the basis for fire prevention. Inspections should be made periodically and correction of fire hazards should be made as soon as practicable. Local fire departments should be consulted for recommendations.

HAND TOOLS

Hand tools, improperly used and in unsafe condition, are the cause of many accidents and injuries. Therefore, the right tool should be used for the right job in the right way. Protective safety equipment should be used where there is a job hazard. The work area should be in a safe condition, clear of hazards, with an adequate working space allowing a solid footing. Tools should be in good condition and used for the purpose for which they were intended.

HORSEPLAY

No horseplay should be permitted on jobs. Many serious accidents and injuries are caused by horseplay and immediate corrective action should be taken if it is repeated.

INSPECTIONS OF TOOLS AND EQUIPMENT

Periodic inspections should be made of tools and equipment so that those that are broken or worn out may be

replaced. Worn or broken equipment should be reported and replaced or repaired as soon as practicable.

LADDERS

Ladders should be inspected periodically and maintained in good order. Safety belts should be used when awkward positions are necessary for the work. Metal ladders should not be used for electrical work.

LANDSCAPING

Personnel should be properly trained in the use of power equipment, especially power lawnmowers. Spark-plug should be completely disconnected and care should be taken while repairing or cleaning equipment.

LIFTING

Lifting should always be done with the leg muscles instead of the back and footing should always be secure. Knees should be bent and back kept straight and body must not be turned or twisted when lifting. Assistance should be secured if load is too heavy or awkward to handle. Use mechanical device for lifting wherever possible.

PORTABLE AND POWER TOOLS

All equipment should be safeguarded by grounding. Wiring and equipment should be checked periodically for defects. Extreme care should be taken when equipment is used in wet areas. Protective safety equipment should be used when using grinders, buffers, or other tools if there is a danger of flying material.

PROTECTIVE SAFETY EQUIPMENT

The need for protective safety equipment in an accident prevention program has proven its value many times and the program cannot be successful if any phase of accident prevention is overlooked.

Safety equipment should be used as designated and its use should be compulsory by workmen performing hazardous work. Eye and face protection should be used in jobs where there is any possibility of injuries, that is, from hand tools, power tools, welding equipment, etc. Foot protection should be used to safeguard against injuries while breaking pavements, tamping trenches, handling materials, etc. Head protection (safety hats) prevent many serious injuries in construction, excavation or electrical work. Hand protection (gloves) should be used to prevent injuries occurring when handling materials, sharp objects, chemicals or electrical equipment. Masks and respirators should be used when such hazards exist such as chlorine, painting or dusty areas. Prevention of accidents due to falls can be minimized by the use of safety belts, scaffold, etc.

SANITATION

Washrooms, toilets, locker rooms, drinking fountains and showers that are clean, ventilated and adequately built keep good employee morale. Adequate, clean drinking water and paper cups should be available at each plant, especially if the employees are exposed to skin irritant materials.

STORE ROOMS

Good housekeeping must be maintained at all times. Space should be well arranged to permit proper storage, handling and movement of materials. Inspections should be made periodically for fire hazards. Fire extinguishers should be in good order and easily accessible location.

ELEVATED TANKS AND RESERVOIRS

The ground area surrounding elevated tanks and reservoirs should always be neat, clean and landscaped, if possible. Tanks and reservoirs should be kept in good condition. Protective fencing should be provided to keep out unauthorized persons. Ladders should be securely fixed. Safety belts should be used when working in high or hazardous positions. More than one workman should be present for work or inspections. Care should be taken

when power equipment is operated to eliminate electrical hazards.

TOOLS AND MACHINES

Protective equipment should always be used when operating power equipment where there is any chance of flying objects or other injuries. Inspections should be made of all tools and equipment for safe operations and necessary repairs or replacements should be made immediately. Repair of power tools and machinery should only be made when the equipment has stopped.

TRENCHING (EXCAVATION - SHORING)

Safe and adequate work area should be well protected with barricades and traffic safety cones for the protection of the worker and the public. Proper and adequate tools and equipment should be available for the job to be done.

Workmen should use proper protective safety equipment, that is, safety hats, goggles, foot guards, shields, etc. Inspections of the trench should be made for possible hazards - checking for possible cave-ins, projections inside trench, housekeeping, etc. Equipment should be operated by authorized and qualified workmen only.

Since most serious injuries occur in the field, extra precautions should be taken of work safety and conditions of men in the trench. Never take chances while workmen are in the trench. Proper shoring and bracing always pays.

TRUCKS AND EQUIPMENT

Trucks and equipment should have routine inspections made. Need of repairs should be reported and made as soon as practicable. Only qualified and licensed operators should be permitted to use and operate vehicles and equipment. Operators and drivers should not permit riders on equipment or permit passengers on trucks or equivalent equipment when it becomes hazardous. Electrical

or other hazards should be checked constantly when moving heavy equipment.

WELDING

Proper protective equipment should be used at all times. Checks should be made for possible fire hazards, cutting or welding in areas of inflammable or explosive mixtures. Only authorized or capable personnel should operate welding equipment.

WORKING AREA

A safe working area must be provided for efficient work to be done. In the field, traffic should be controlled by the use of traffic cones, barricades, flags, etc. to give protection to the workmen as well as to the public. In the material yard and store rooms, good housekeeping and properly planned storage and work areas must be provided to permit safe working practices. In the shops, plants and offices, planned arrangements must be made to provide safe working areas to enable the most efficient production.

CONCLUSION

Through continuous research and accident experience, standard safety rules and safety devices have been worked out for most of the operations which are common activities in water utilities. We, as supervisors, are expected to know about these rules and devices, and we are also expected to use them. We must broaden our horizons in safety, by learning what others are doing, so that we may have a wider understanding to help us work out protective devices and safe practices of our own operations. No matter how perfect the mechanical device or how thorough the research and development have been, the degree of hazard for safety of the operation rests in your hands.

CHLORINE

SAFETY METHODS OF HANDLING CHLORINE

Chlorine is one of the work-horse chemicals of industry and in any discussion of the subject some of the properties of the chemical should be considered first.

Despite the fact that chlorine handling equipment is well designed, a fact well-proven by the number of people who have been handling chlorine for many years without an accident, it must be recognized that chlorine is a potential killer if equipment becomes defective or people become careless.

There is no such thing as a foolproof method of handling chlorine. Therefore, we will deal with the potential hazards which can be avoided or eliminated if the lethal properties of chlorine are recognized.

By itself, chlorine is neither explosive nor flammable, but it will support combustion.

For example, steel at a temperature of 483°F will ignite in the presence of chlorine and burn quite readily. Other metals will act similarly at slightly higher temperatures.

The least detectable amount of chlorine in the atmosphere is about 3 1/2 ppm. The maximum amount that can be inhaled for one hour without serious effects is about four (4) ppm. At fifteen (15) ppm, chlorine will cause irritation of the throat; at thirty (30) ppm, it will cause serious spells and at forty (40) to sixty (60) ppm, it is extremely dangerous for one half hour exposure. A few breaths of air containing 1,000 ppm would be lethal.

ESSENTIAL ITEMS REQUIRED

1. A two-wheeled chlorine cylinder hand truck.
2. A 10 or 15 minute air pack of approved design.
3. Where one-ton cylinders are in use, a self-contained

air pack with a full face piece of approved design and make, and with a spare cylinder.

4. A wall mounted steel cabinet with glass panels for storing the air pack.
5. Canvas or cotton gloves coated with a waterproof plastic.
6. A bottle of five percent concentrated ammonia for detecting chlorine leaks (not household ammonia).
7. Signs - "Turn on Exhaust Fan Before Entering".

Chlorine is shipped in three types of containers, 150 pound cylinders, ton cylinders and tank cars. The 150 pound container is the more familiar item. These cylinders are equipped with a single Chlorine Institute standard cylinder valve which has a brass body and a Monel stem. There is a packing gland containing two rings of packing and a fusible plug. The fusible plug is located on the side of the valve opposite the outlet and is designed to release pressure in the cylinder should the cylinder temperature rise above 160°F on the outside.

The standard way of making a connection to this valve is with a yoke clamp, adaptor and a small head gasket. These three items are supplied free by the chlorine suppliers. When connecting a cylinder to the chlorinating system, the following steps shall be followed:

1. Secure the cylinder to a building column or a solid upright support.
2. Remove the protective bonnet. If the cylinder has been exposed to the weather for a long time the threads at the base of the bonnet may have become corroded, in which case a few smart raps on opposite sides of the bonnet will loosen it so that it may be unscrewed easily.
3. Remove the brass outlet cap and any foreign matter which may be in the valve outlet recess. When removing this brass outlet cap, stand to one side and remove it carefully, as there is the possibility of some chlorine being trapped under this cap.

4. Check outlet recess for old lead washer, a 3" nail can be used.
5. Place a new lead washer in the outlet recess.
6. Place a clamp over the valve and insert the adaptor in the outlet recess and then fitting the adaptor in the clamp slot, tighten the clamp screw.

The only reliable method of determining the contents of a cylinder, is by weighing. The pressure in a cylinder depends on the temperature, not upon the amount of chlorine in the container. When convenient, it is recommended that the cylinder stand on a scale throughout the entire period of discharge. In any event, the only sure method of determining whether or not the cylinder is empty is to weigh the container and check its weight with the tare weight stamped on the cylinder's shoulder.

OPERATING SAFETY INSTRUCTIONS

1. A self contained air pack must be worn when it is necessary to locate and stop small leaks in the piping or when making any repairs or adjustments to leaking equipment.
2. Wear plastic coated gloves when changing cylinders.
3. When connecting the piping from the cylinders to the chlorine machine or whenever it is necessary to break a connection and recouple it, a new lead or fibre washer must be used each time.
4. Do not lift a cylinder (150 lbs.) up onto the scales. Use a ramp.
5. Whenever possible, two men should be present when changing chlorine cylinders.
6. A self-contained air breathing unit must not be used unless the air cylinder is fully charged. Cylinders must be completely recharged after each use.
7. When a leak occurs in a chlorinator room, do not open or leave open any doors leading into any other part of the building. Only doors to the outside should be opened.

8. Water should never be applied to a chlorine leak because of the added corrosive action created by the water and chlorine mixture.
9. The chlorine exhaust fan must be turned on at all times when entering the chlorine room, whether for a routine check or for servicing or repairing leaking equipment while wearing a mask.
10. In all cases where the concentration of the chlorine gas in the air is unknown, a self-contained air pack must be worn.
11. Do not start up or operate a chlorinator or turn on a chlorine cylinder unless adequate protective equipment (air pack respirator) is on hand in the chlorine room area.
12. All persons using the gas protective equipment must be trained in its use and maintenance.
13. All removable parts of the chlorinator such as cylinder clamps, metal hose connections, couplings, headers, valves, etc., should be removed at the end of the chlorinating season, cleaned and inspected, and worn and damaged pieces replaced.
14. When using chlorinated powder or chloride of lime for dusting etc., a proper type of eye shield and gloves must be worn. The piping from the cylinders to the header located on the wall or to the chlorine machine must have an inverted loop of not less than 10" in diameter in its length. The loop acts as a flexible coupling.

CHLORINE

1. If at any point in the chlorine gas piping that chlorine gas has been or is leaking and a green slime appears, this slime will coat the area to varying degrees of thickness, depending on the concentration of the leak and the length of time it has been leaking.

Do not wipe this slime from the place of leakage with a wet cloth even if the leak has been repaired. Always use a dry cloth. The dampness of the wet cloth combines

with the gas and/or the chemical reaction that formed the slime. This worsens the leak or (if the leak has been repaired) creates another leak.

If this green slime has dried to a dust or if it is necessary to remove this dust from any piece of equipment, do not blow it with your mouth or brush or wipe it unless the area is completely ventilated. Avoid breathing this dust. Even minute particles are highly dangerous.

2. Under no circumstances must chlorine cylinders be moved or bumped when they are being used or connected to the chlorinator.

If it is necessary to move a cylinder that is in use, the same procedure must be followed as for changing used or empty cylinders.

3. Renew all metal chlorine gas piping leading from the cylinders to the header or chlorinator after each season of use.

If chlorination is continued for the full year the pipes must be replaced at the end of each year of operation. Do not attempt to clean and reuse the pipes.
All black iron pipes used as header pipe for gas or liquid chlorine to be replaced after 5 years of service.

CHLORINE CYLINDERS - HANDLING AND STORAGE

Small Cylinders (150 lbs.)

Small cylinders must not be handled roughly, allowed to drop or fall to the ground or against each other. Use a two-wheeled cylinder truck when moving full or empty cylinders.

If a hand truck is not available or if space or conditions prohibit its use, it is then permissible to move full or empty cylinders by rolling them by hand upright on their bottom edge. Care must be taken so that the protecting bonnet does not become loosened and/or allowed to fall off.

The protecting bonnet over the cylinder valve and

the cap on the threaded end of the valve must be kept on the cylinder at all times, empty or full, except when being used.

Cylinders must be stored in an upright position in a dry area and prevented from falling over, etc., with a safety chain anchored to the wall with a snap hook and placed around the outside of the cylinders. Do not lift cylinders with a rope or chain sling. Read the instructions on the green tags on the cylinders.

One Ton Cylinders

One ton cylinders must be moved by an approved lifting bar and hoist, never by rolling them along the floor.

General storage conditions are the same for both large and small cylinders. Chlorine cylinders of any size should not be stored:

- (a) Near combustible material such as oil, gasoline and/or other wastes.
- (b) On an uneven floor or one wet or covered with debris.
- (c) Near the inlet of a ventilating or air-conditioning unit.
- (d) In a subsurface location.
- (e) Close to any source of heat such as a furnace, heating elements or radiator.

Outside storage areas should be sheltered from the direct rays of the sun.

A ton container has two valves, very similar to the one on the 150 pound container, in fact, the only difference is that these valves do not have a fusible plug. The ton cylinder has three separate fusible plugs in each end. These will also melt at 160°F and discharge the chlorine from within. The delivery rate of chlorine from a ton container will depend on the temperature of the liquid in the container, but an average flow is about 20

pounds per hour of chlorine gas. The one ton cylinder must be positioned on the scales, so that the two discharge valves are above one another. The top valve will produce chlorine gas. The bottom valve will produce chlorine liquid.

Hazards of Hooking Up Warm and Cold Cylinders Together

Should your storage of full containers be considerably cooler than the room in which they will be used, special precautions should be taken to avoid the following conditions. If a new cold container is hooked up in a parallel with a warm container, the chlorine gas will condense into the cold container so that its liquid content will increase. It can increase so that it becomes a liquid full. If, when in this condition, the valve was to be shut off, it then becomes a bomb. The container will naturally warm up in the new warm surroundings and, as it warms up, the liquid will expand exerting tremendous hydrostatic pressures on this cylinder. There is a very good chance that this cylinder will burst creating a very serious situation.

There are two solutions to this problem. The first and probably the best is that full containers be stored at the temperature of the location where they are going to be used. The second preventive measure is that when a new cylinder is hooked up in parallel to other partly used cylinders, the valve on the new cylinder should always be left open for several hours until it has reached a common temperature.

* * *

Dry chlorine gas does not attack most common metals. Most metals however, will corrode at a rapid rate when exposed to wet chlorine. Leaks occurring in the presence of water or moist air tend to increase rapidly in volume, due to the corrosive action of this acid. Pipe lines for handling dry chlorine should be made of extra heavy black iron steel pipe. Although copper piping may be used if desired, gaskets made of asbestos or lead are recommended. The use of rubber gaskets on chlorine lines should be avoided. Where screwed fittings or joints are required, it is essential that all threads be clean and well formed.

Graphite, red lead or litharge may be used as pipe dope. In making joints, care should be taken to ensure that no dope is allowed inside the pipe as the oils will be chlorinated to form a gummy substance which will clog in the system. Similarly, all cutting oil should be removed from the inside of the pipe before erection. In the case of larger consumers of chlorine, it may be necessary to withdraw liquid from the containers and vaporize it in a vaporizer. In this case, the utmost precautions should be taken to ensure that at no time a liquid chlorine line is shut off at both ends with a valve without having protected this line with an expansion chamber to prevent hydrostatic pressure rupturing the line. As a general safeguard, all chlorine pipe lines should be subjected to a 300 pound hydrostatic pressure test before the line is put into service. Immediate drying of chlorine pipe lines into which water has been accidentally introduced or which has been opened for repairs or cleaning is essential if corrosion is to be kept to a minimum.

* * *

The chlorine industry in North America has experienced between one and two defective containers per thousand containers shipped. The majority of these defective containers have what is known as a "turning spindle." This is a stripped thread on the valve body. This is normally discovered when trying to close off a cylinder already in service.

After the valve is opened and the flow of chlorine adjusted you should check that the packing gland is tightened down. A check of the connections should also be made, with an ammonia bottle, for any leaks. The maximum discharge rate for a single 150 pounds cylinder is about two or three pounds per hour.

When discharging gaseous chlorine, a cylinder is actually re-frigerating itself. As the liquid chlorine inside the cylinder vapourizes, it takes up heat from the surroundings. No doubt you have noted that when a cylinder is nearly empty, frost forms on the outside of the cylinder. This acts as an insulation and reduces the amount of heat that the cylinder can get from its surroundings. This condition lowers the chlorine pressure considerably. The frost may be removed by scraping, or by circulating warm air around the cylinder with a small fan.

Do not, under any circumstances, apply hot water or external heat to a cylinder to speed up the supply of chlorine. This is an extremely dangerous practice. There is another simple method for getting around this slow delivery of chlorine at the end of the cylinder and that is to connect another cylinder to a manifold. When the first cylinder becomes covered with frost, shut it off and use the fresh cylinder until the first cylinder has warmed up to room temperature and the pressure has been restored. The most simple way of overcoming this problem is to continue using the chlorine until the cylinder is empty. However, there are some circumstances which merit more rapid action. Quite a number of OWRC plants use piping from the chlorine cylinder to the header or chlorinator with a valve located on the pipe at the cylinder end. This valve can be closed as a shut off, the pipe then disconnected at the header (the header connection then capped) or disconnected at the chlorinator. The cylinder may be moved to a less hazardous location and a call put into the supplier who will come and deal with the cylinder. Another possibility is to bleed this cylinder gradually to atmosphere. Another type of leak in a container is a leak around the packing gland. With the valve shut off, the packing nut may be removed and the valve repacked without any danger. Sometimes merely tightening the packing gland nut will suffice. Fusible plugs occasionally develop leaks. This is usually due to corrosion from moisture, either internally or from the outside. Again the supplier's personnel can be called in and apply a suitable clamp over the fusible plug to stop the leak. The adaptor clamp can also be used to stop this leak. The procedure would be to take a flat file and file the area around the fusible plug flat, and apply a small patch of rubber gasket material with a follow-up piece of metal and clamp this firmly in place. It should be carefully noted, however, that the cylinder is now without protection from high temperatures so that every attempt to use this cylinder up as rapidly as possible should be made.

It is extremely important that a leaking cylinder is positioned so that gas rather than liquid is escaping. This cuts down the amount of chlorine fifty-fold. Chlorine lines can be broken through mishandling, chlorine can be discharged into the chlorinating room by leaving the wrong valve open, etc.

When working with chlorine, care should be taken to follow the prescribed procedure so that mistakes are not

made. However, suitable gas masks should be available so that emergency measures can be taken. The chlorinating room itself should be adequately ventilated with a separate ventilating system capable of removing the air from the room once every four minutes. This ventilation should be located at a low level in the room because the chlorine gas is heavier than air. Ideally, there should be two exits from a room containing chlorine containers and the doors should open outwards to facilitate rapid exit. Gas masks should be located just outside the chlorinating room as should the switches for the ventilating system.

FIRST AID IN CHLORINE HANDLING

D. J. Ellis

Ass't. Safety Officer
Division of Plant Operations

Object: To instruct in the proper first aid treatment given to a chlorine-gassed person and the proper methods of artificial respiration.

If you, as an operator, came upon one of your fellow workers lying in a chlorine gas-filled room, unconscious and possibly not breathing, what would you do? Would you leave him there, or would you rescue him?

The very first thing to remember before entering the room is that the chlorine gas that caused the operator to black out is still there, and, therefore, you as a rescuer must put on a fresh "Air Pack" for your own protection, or else there will be two victims instead of one. "NEVER" enter a gas-filled area without a fresh "Air Pack" on. Do not use a "Canister Mask". The concentration of chlorine gas in the room may be too high a concentration to permit the use of the canister mask. The canister mask does not produce or contain fresh air; it only contains activated charcoal which will filter low concentrations of chlorine gas.

With the "Air Pack" on and operating, it is now safe to enter the gas filled room to rescue the casualty.

We must now do the following:

- 1) Call medical aid (doctor, Fire Dept. or ambulance) and tell them to bring oxygen equipment and a respirator.
- 2) Lay the casualty down on his back (prone position) and treat for shock (blanket over and under casualty) and start artificial respiration immediately if necessary.
- 3) Administer hot coffee only if casualty is conscious.
- 4) Apply burn lotion or oil for relief of skin irritation (DO NOT APPLY WATER).
- 5) DO NOT LEAVE your casualty alone at any time until medical aid has arrived or you have taken your casualty to medical aid.

- 6) If you have a self-contained "Air Pack" (Scott, M.S.A. or Survivair) put it on a conscious casualty as it will help his breathing.
- 7) Throat irritation and coughing will be greatly relieved by a throat lozenger.

Chlorine gassing is not accumulative, however, your lungs will be more sensitive to it in the future.

If a large quantity of liquid chlorine is spilt on you, get under the deluge shower immediately to dilute the chlorine and wash it off thoroughly.

The self-contained fresh "Air Pack" comes in varying sizes from 1/2 hour to 7 minutes.

The size used by the OWRC in most of the projects is the 15-minute size. The 1/2 hour size is used as a back up air pack in our larger plants.

The smaller size makes for easy access through man-holes where the larger one on a man's back prevents this. The small "Air Pack" can be put on in a matter of 10 to 12 seconds, whereas the larger one takes an inexperienced operator about 3 minutes to put on. On a rescue seconds count, especially if the man has stopped breathing, since artificial respiration must be started within 4 minutes of when breathing ceases, or the chances of saving a life are very small.

The "Air Pack" is put on by slipping your arms through the shoulder straps and adjusting to the most comfortable position. On the small pack the air valve must be turned on before putting the pack on. On the larger, it can be turned on any time. The hose is attached and the face mask put on.

(Demonstration)

ARTIFICIAL RESPIRATION

There are many types, the most common used are mouth-to-mouth (oral) and revised sylvester methods.

General rules for the treatment of a person who has stopped breathing:-

- 1) Remove the cause from the casualty or the casualty from the cause.
- 2) Ensure a free air passage (tongue not in the way and keep the head well back).
- 3) Start artificial respiration immediately and continue until natural breathing resumes or a doctor says to stop, or rigor mortis sets in.
- 4) Utilize and keep nearby:
 - a) blankets
 - b) shelter
 - c) by-standers to relieve you; go for medical aid; keep crowds back.

Demonstration of the two methods of Artificial Respiration.

CONCLUSION

First aid and rescue is a combination of common sense, a cool head and practice. Of these three, practice is about the most important. A cool head and common sense we develop, but practice in the use of first aid and rescue equipment is something you must do every month if you are to be proficient in saving a man's life in an emergency.

CHEMICAL FEED PUMPS

P. D. Foley, Supervisor

Technical Advisory Services Branch - OWRC

There are many types of chemical feed pumps available to the water treatment plant operator. The common piston pump is sometimes used but is best suited to water pumping. It is too expensive when made of suitable chemical resistant materials and is also difficult to maintain.

The plunger pump is normally used on chemical feed particularly where a high pressure or a high degree of accuracy is required.

For normal water pressures the most suitable pump is the diaphragm type. It is available in a wide range of materials which are suitable for most chemical feed applications, and also in an assortment of diaphragm diameters and types. The diaphragm pump is supplied with single, dual or triple pumping heads. In the last two types, they are usually alternate feed.

Drawing #1 illustrates a fairly standard type of pump-head arrangement. Power is supplied by a small electric motor geared to a crank and pushrod. The rod is not directly connected to the pump diaphragm but rather, is only used to push out the diaphragm during the pumping stroke. During the suction stroke the diaphragm is drawn in by a spring. The chemical dosage is controlled by limiting the distance the spring can push back the diaphragm. Generally a small eccentric is used to limit the travel of the spring and through it the diaphragm. With the eccentric in its fully opened position the stroke is 100 percent and the pushrod is always in contact with the return spring. At any stroke settling less than 100 percent, the spring and consequently the diaphragm will follow the pushrod on the suction stroke until the spring comes up against the eccentric, and it will stop at that point. The pushrod, however, will continue its suction stroke travel with the crank and then start moving forward on its pressure stroke. Again depending on the setting of the eccentric, it will contact the spring and diaphragm and start them moving forward on the pressure stroke.

The most common diaphragm material is "hyplon" which is a flexible plastic material that has extreme chemical resistance.

The check valves are of various materials and made in a variety of shapes. The most common type is the poppet valve, which is shaped like a mushroom and made of a chemical resistant plastic such as "Koroseal" (a plasticized form of PVC). The stem of the mushroom runs inside the connecting passage of the discharge fitting, as shown in drawing #1, and has fluted sides to allow the chemical to pass by it. The cap of the mushroom acts as a check valve and seals on the top of the passage in the discharge fitting.

The poppet valve is used on liquids of water-like viscosity, and specific gravity which will not attack the plastic. Because of its superior sealing properties as a check valve, it is preferable to the ball type. Where higher viscosities and specific gravities are encountered, the glass ball check is used due to its greater weight. If even more weight is required, a stainless steel ball is used. Glass ball checks are usually used for active chemicals such as potassium permanganate. They are not suitable for fluorides as they attack glass.

Where the feed pump discharges into a pipe with negative head, such as a pump suction, or discharges at a level below the pump, it is necessary to provide an antisiphon valve in the pump discharge. The antisiphon valve is shown in drawing #2. The valve is generally mounted directly on the pump body in place of the normal discharge fitting and, consequently, contains the discharge check valve. The spring loading on the diaphragm provides a normal load of 10 psi. In operation, the pressure of the liquid in the pump discharge opens the valve by the pressure at "A". The liquid passes over the seat into passage "B" which is an annular ring completely surrounding inlet "A". A discharge port "C" with a boss for the discharge hose is provided. If a suction is provided at point "C", it will draw down the diaphragm against the seat but will not withdraw any chemical. The pump pressure is more than enough to open the diaphragm when pumping.

Where it is necessary to feed more than one chemical at one location, a multiple head feeder can be used. It must be remembered, however, that if the single motor fails there will be no chemicals fed. From the point of view of control, it is more convenient to feed only one chemical through one pumphead, as the feed rate of the individual chemicals can be varied independently of each other. In an emergency however, many chemicals can be mixed and fed through a single pump--hypochlorite and lime are sometimes fed together. The point here is that with single head feeders on a multichemical feed operation, the loss of one feed pump does not always prevent the feeding of all chemicals.

The standard diaphragm pump is suitable for use only where the rate of flow is constant. In locations where the water flow rate varies, it is necessary to vary the chemical feed rate in order to maintain a constant dosage. A water meter or some other similar metering device must be installed to measure the flow and put out a suitable signal to control the pump. This can be an air pressure signal operating at a 3 to 15 psi range, where 3 psi equals zero flow and 15 psi equals 100 percent of flow, or it can be a pulse duration signal. A common type gives a 4-second pulse at zero flow and a 26-second pulse at full flow, so that the feeder would operate once every 30 seconds, and would run for a number of seconds between these two values, depending on the water flow rate. In some cases a variable speed drive is used and the output speed of the motor is controlled according to the water flow rate. The control could be either the air signal or pulse duration. The control can either vary the stroke length proportional to flow or vary the ON time of the motor proportional to flow. The first method is more preferable. Since the strokes per minute do not change, it will not materially alter the time between chemical additions. Where the ON time of the motor is varied (pulse duration), the number of times chemical is added per minute can become extremely low.

Even in some constant speed applications the stroking speed must be considered. If your pump is one in which the pump-head and motor are separate with cone pulleys and a V-belt, always operate at a high stroking speed. You must use low stroke length even though it does increase the pump wear, but it will provide the optimum and most even application of chemical. If you are concerned about the time between pulse of chemical, you should consider a dual headed feeder. Most of these feed alternately through the heads rather than simultaneously, and a much more even feed is obtained.

In some installations there is a problem of mixing the feed chemicals and the water in a pipeline. This can be overcome through the use of an inline motor-driven, mechanical mixer, or with inline mixing chambers utilizing a chemical packing such as "Berl Saddles" or "Raschig Rings".

At least one manufacturer provides a water-driven, chemical feed pump, paced by a water meter, which is flow proportional and feeds the chemical more than 50 percent of the time. The feed pump is driven with a water pressurized diaphragm in which the water is allowed to slowly enter during the power stroke, but is vented rapidly on the spring-returned, suction stroke. This does serve to provide chemical feed for a larger percentage of the time.

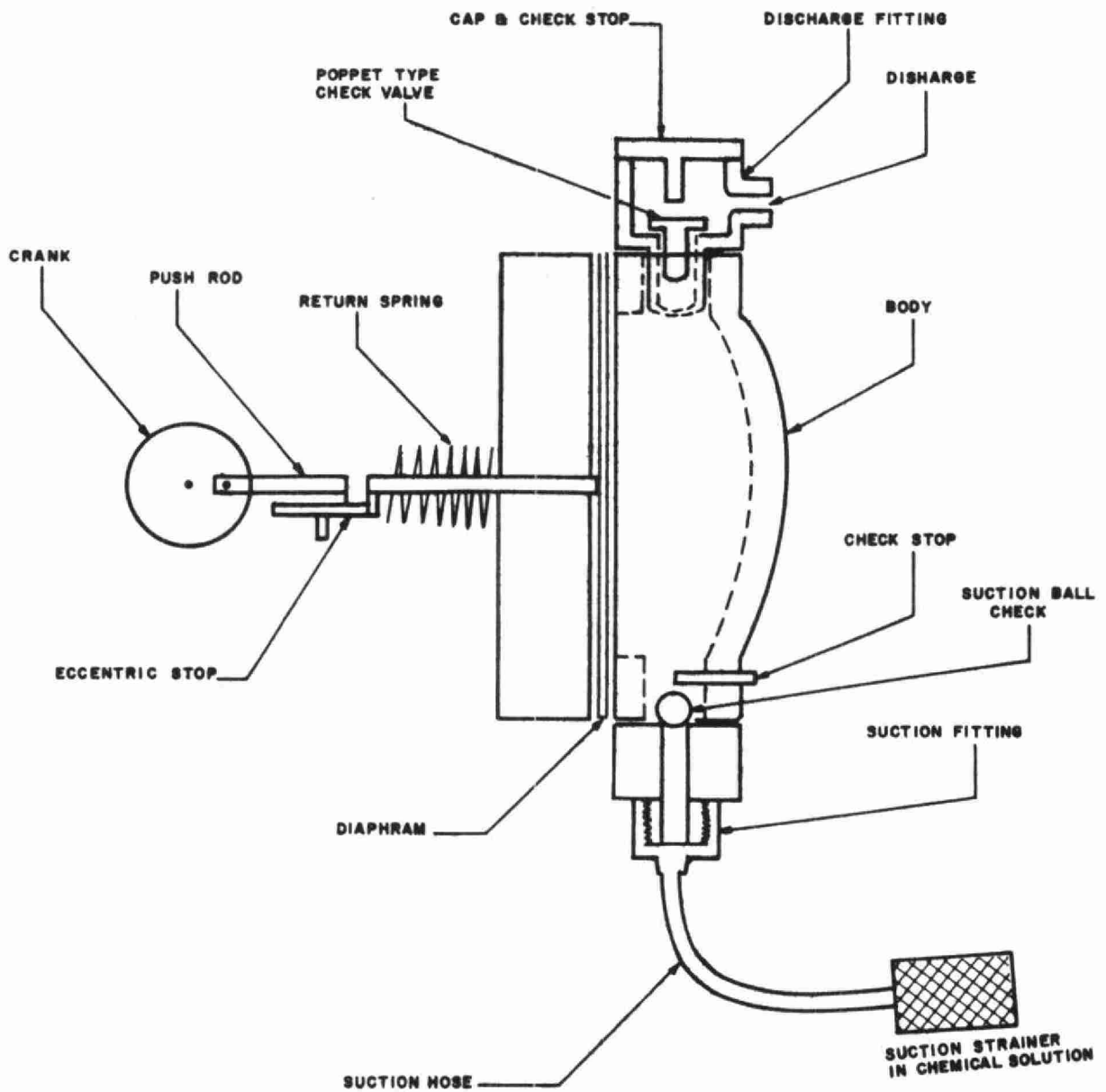
When chemical feed pumps are used on slurries such as lime, diatomaceous earth or carbon, they must be equipped with flushing lines as the slurry will otherwise settle out and accumulate in the pump and piping. The clean flushing water must be introduced on the suction side of the pump to clean both sets of check valves, as well as the diaphragm chamber and the discharge line. Most manufacturers supply pumps with optional flushing connections on the suction valves and include with them the necessary automatic timers and valves to control the flushing operation.

Where two chemicals such as lime and hypochlorite are being fed, a dual headed pump can be utilized and the chlorine pumped through the lime head to provide flushing. It must be remembered, however, that this procedure will reduce the output capacity of each of the heads to 50 percent of their rated capacity.

Where the pump is used on hypochlorite solution, a white scale of calcium carbonate will build up on the inside of the pumphead and on the check valves and tubing. A mild solution of muratic acid (mix 2 volumes of water with one of acid) will normally remove the scale. The general procedure is to pump the acid through the pump to waste, then rinse with sodium bicarbonate to neutralize the acid.

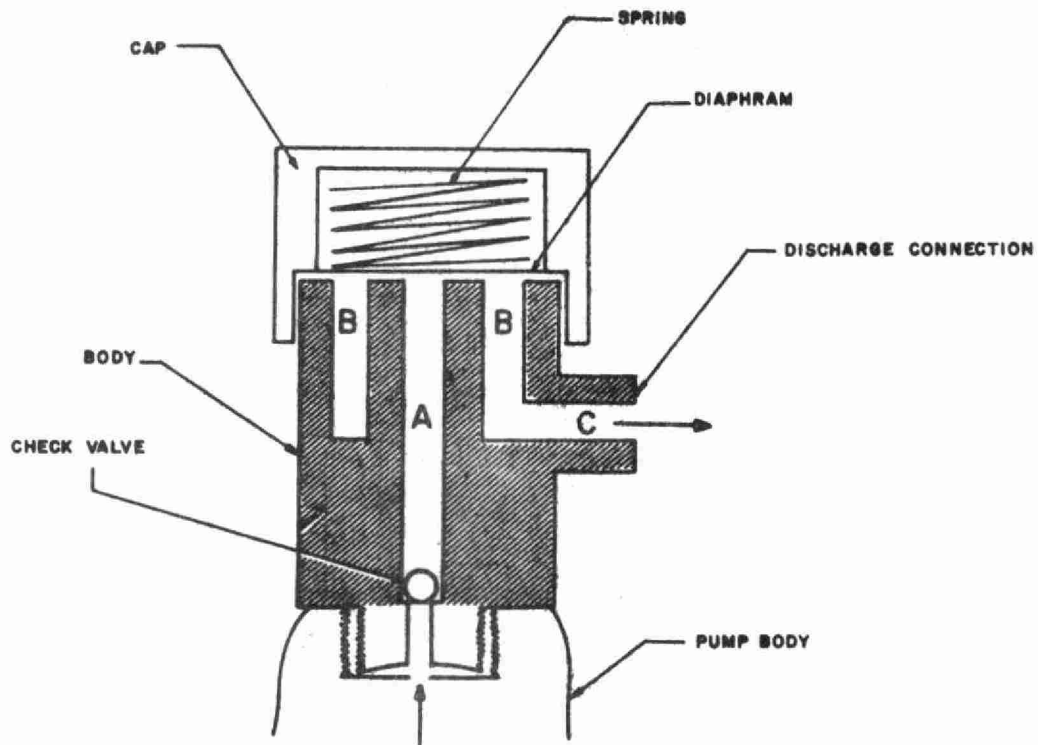
When a more accurate control of the chemical flow is required or where a high pressure is encountered, a plunger pump is generally used. Drawing #3 illustrates this type of pumphead. For most chemical applications, a ceramic plunger is utilized with a stainless steel or hastalloy cylinder. Unlike the diaphragm pump, the plunger in this pump is attached directly to the connecting rod and moves with it on both suction and pressure strokes. A more sophisticated method of stroke adjustment such as the "Scotch Yolk" is utilized and proportional feed is attained by automatic stroke control, variable speed drives, or by interrupting the power supply to the motor as outlined for diaphragm pump control. With a standard 110 or 220 volt single-phase motor, no more than 4 start-stops per minute can be tolerated without burning out the starting winding of the motor.

DWG. No: 1
DIAPHRAM PUMP



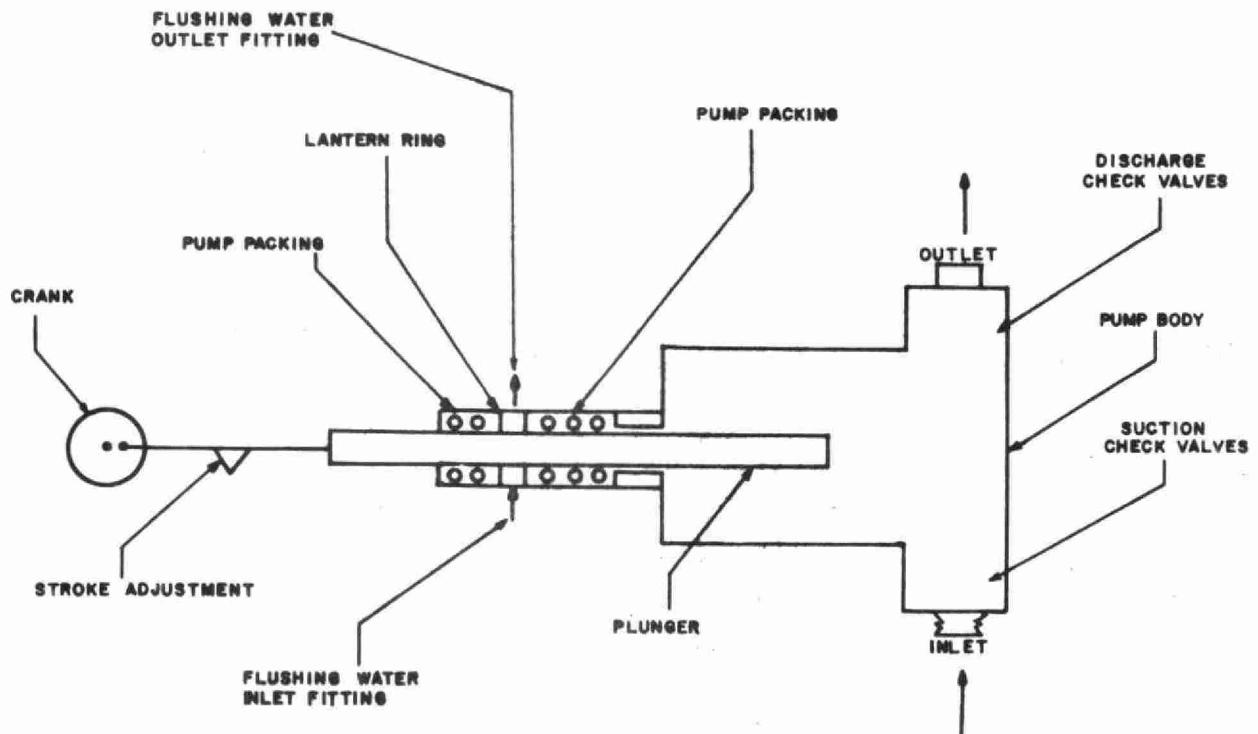
Q - 6
DWG. No: 2

ANTI SYPHON VALVE



DWG. No: 3

PLUNGER TYPE PUMP



INSTRUMENTATION - PART 1

F. H. Freemantle

Instrumentation Specialist
Division of Plant Operations

Today instrumentation is somewhat of a confusing word, depending on a person's acceptance of its meaning. It is sometimes associated with automation but I like to think of instrumentation as a system of control which can measure a process and control some or all parts of it.

Quite often we mention instruments, which is a particular unit, when what we are actually referring to is instrumentation. We are all familiar with our automatic appliances, such as toasters, clock radios, stoves, furnaces, etc. These all have forms of instrumentation in as much as they have an automatic control of some process, such as toasting bread, turning on the radio, baking, heating our houses, etc., so it is not such an imposing word after all.

When used in the industrial field it does measure and/or control a process. Now a process is any operation from pumping water to providing treatment or manufacture of a substance. In the water works field instrumentation will measure the flow of water, control the pressure, pH, chlorine residual etc., level of reservoirs, and in so doing, will automatically control pumping, filter backwashing, chlorine dosage, alum dosage, etc.

Because of this type of process control we talk of an 'era of automation'. Due to man's inability to maintain a constant control of equipment without faltering over an indefinite period of time, we use instruments and associated controls to do so. This does reduce the man power required but will improve the quality of those required to maintain a plant. The exacting requirements of today's operations has caused a large increase in automatic control and by this means all parts of a process can be observed and controlled from a central office.

Here we are concerned with that instrumentation which will help us improve and maintain the quality of water which we are supplying to the water system. In the very simplest system we are merely pumping from a well or other source of water to a reservoir or tower, while in the more complex systems we will pump from an intake, through a filtering or treatment system, to another pumping station and into a final system or reservoir.

As with most things we do, we want to know what we are getting and the cost of the operation. To do this we must naturally know the flow or quantity of water supplied, and if treatment is required, to automatically control the quality.

The first thing to do is to measure the flow by means of a flowmeter operated mechanically or by differential pressure types. The mechanical type we are all familiar with, probably have one in the basement of our house, on which we are billed for our consumption of water. The differential pressure types, which we deal with here, allow us to control our system more easily and we will examine several methods of how this is done.

Pressure is force per unit area, e.g. pound per square inch or pound per square foot. A common way of measuring this is by use of a manometer which balances a column of liquid in static equilibrium. If we take a piece of glass tubing and bend it to form a 'U' and fill it partially with a liquid, we then have a very simple form of manometer. It is one of the most accurate ways of measuring relative pressure.

With a simple bent tube filled with some liquid such as water or mercury and open at both ends to atmosphere, we note that the liquid will balance so that both levels are equal above a reference line. (Diagram 1A) Anywhere in the tube we have an equal pressure point to another at the same level from the reference line. It does not matter that one side of the tube is larger than the other as both are subject to the same pressure. All points at equal distance from the reference line in the liquid are subject to the same pressure. (Diagram B)

When we introduce an external pressure to one leg, the other remaining with the same pressure, we find that the liquid in one leg will go down while the other goes up. If we take a point p_a in the short leg and point p_b in the long leg that are equal levels above the reference line and point p_c to represent the distance from p_a/p_b to the level of the short leg, we find that equal pressure is represented on p_a by p external plus p_c and on p_b by p_1 plus $p_c - p_1$ being the pressure of the higher column of liquid. The distance between the lower and higher points of the liquid, h_1 , measured and applied to the specific gravity of the liquid will tell us the pressure applied in respect to atmospheric pressure. If we apply two pressures the distance h_1 will tell us the differential pressure on the system.

Differential pressure types of instruments use a change of pressure to determine velocity and hence flow. The principle used here is that a flow of liquid through a constriction in a pressure conduit results in a lowering of pressure at the constriction. This pressure change is proportional to or reflects the velocity of the fluid flowing through the restriction.

The device used to first provide this differential pressure is known as a Primary Device, and the most common forms are :

- Orifice Plates
- Venturi Tubes
- Dall Tubes
- Pitot Tube
- Flow Nozzle
- Elbow Meter

All these devices use a change in pressure and operate either a manometer type of instrument or a differential pressure transmitter.

The differential pressure method of measuring flow is probably the most common, however, flow measurements can be made in open channels by the use of a parshall flume or the use of a weir plate. With a parshall flume it is common to use a stilling well and float which in turn will indicate the level of flow through the flume. To measure the flow over a weir, a bubbler tube can be used and with a fixed discharge of air, the head pressure on the bubbler tube will be an indication of the flow.

By the use of suitable levers, gears, etc., this change of pressure or level can be indicated as a flow value, it can also record or transmit the information to another point where it can indicate, indicate /record, indicate/record/control, another function such as pumps.

The primary device along with a transducer, which is merely a means of changing one type of signal to another, with an indicator, is known as a transmitter. That unit which receives this signal and either indicates, records, or indicates and records, is known as a receiver. These units may be in the same box cabinet or they may be separated by a few feet or a few miles. When the information is transmitted to another location it is known as telemetering.

The transducer along with the associated units are known as secondary devices. These secondary units are divided into three groups, namely :

- Mechanical
- Pneumatic
- Electrical which includes electronics.

The mechanical type of instruments are operated by rods, gears, linkages and cables connected to the pressure take off on the primary devices. This, of course, eliminates lengthy piping arrangements which must be leak free. Mechanical units usually allow much flexibility in that portions of the unit can be removed and replaced without disrupting the flow of the material being measured. Disadvantages are in the lag of the instrument due to inertia and friction of the mechanical parts, slippage in the linkage, wear and breakdown of the moving parts and it does require considerable lubrication.

The pneumatic type of instruments, while using mechanical linkages and parts for indication, are using a varying controlled-air pressure ranging from 3 to 15 psi. This signal can be transmitted by piping over distances up to 1500 feet to operate the required instrument. The advantages of this system is that the installation and maintenance costs are low while a continuous signal output with an extensive sensitivity to change in the variable being measured is provided. The main disadvantage is the relative short distance the signal can be transmitted and that a clean dry air supply is required.

Electrical types of instruments will naturally use some mechanical linkages for indication but the signal is an electrical current or voltage change. This can be transmitted over great distances between the transmitter and receiver with little loss of signal strength or a time lag that is apparent in other systems. The cost of this type of system is usually a little higher but recent advances are causing it to be used more frequently in the smaller systems of control with a consequent decrease in cost.

To return now to the pneumatic type of instruments, you will note that there are two illustrations of differential pressure transmitters. In the Bourdon tube type the signal pressure is applied to the element and it is the twisting effect of the Bourdon tube which is used to provide an indication or to do some other work.

With the bellows type of differential pressure transmitter use is made of a force beam. This beam is set on a pivot and at one end two bellows are placed for the two pressures of the signal and at the other end there is a balancing bellows with a 'flapper' nozzle, air supply and indicating gauge. With a change in the pressure at the low side there is a corresponding change in the position of the beam. The changing position of the beam opens or closes the orifice through which a constant air supply is flowing. The balancing bellows provides a constant pressure to the force beam according to the position of the beam in relation to the orifice. This reflected pressure is used to give an indication of the pressure applied to the force beam and is in turn a direct relation to a flow measurement.

The indication of flow as provided by the d/p transmitter can be used to operate an electrical type of signal transmission. One type of electrical instrument uses a revolving cam across which an arm rides and it is the length of time which the arm is on or off the cam which gives the pulse duration of the electrical signal. This signal at the receiver operates a magnetic clutch arrangement, which will move the indicator up or down according to the change of pulse duration.

Another type of electrical instrument uses a variation in current caused by a change in a magnetic field, or a change in position of a potentiometer. When the position of the iron core is changed in the magnetic field the flux density is changed causing a change in the current flowing in the external circuit. This also applies to the change of the position of the arm of the potentiometer which will change the current flow in that leg of the bridge circuit.

The electrical instruments are becoming smaller due to the use of transistors and also are becoming cheaper by the more prevalent use of this type of unit.

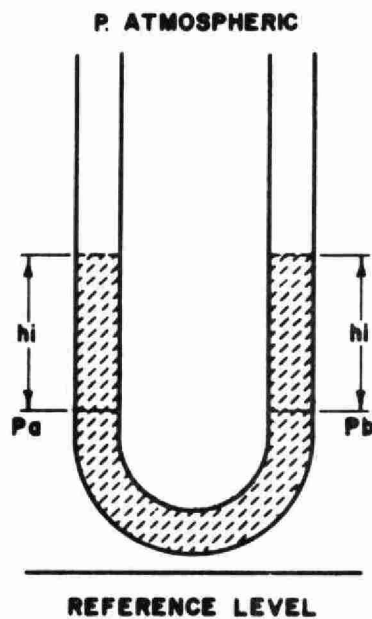
While we have covered a brief outline of instrumentation in regards to flow measurements, we must not forget the other measurements and controls that are necessary. As mentioned earlier it may also be necessary to control the addition of chemicals to the water or to control a filtering process. The control of chemicals to the water may be done by continuous sampling or measuring for chlorine content, pH, or other required information, and these measurements through an instrument controller will maintain a set value, or dosage.

The number of pumps required to maintain a certain level of water in a reservoir or tower can be controlled by the rate of flow as indicated by any one of the flow indicators, by means of suitable control circuits. The automatic backwash of a filter can be done by the measurement of the pressure across the filter bed, and at a predetermined value will automatically shut off the flow of water through the filters and proceed with the backwash operation.

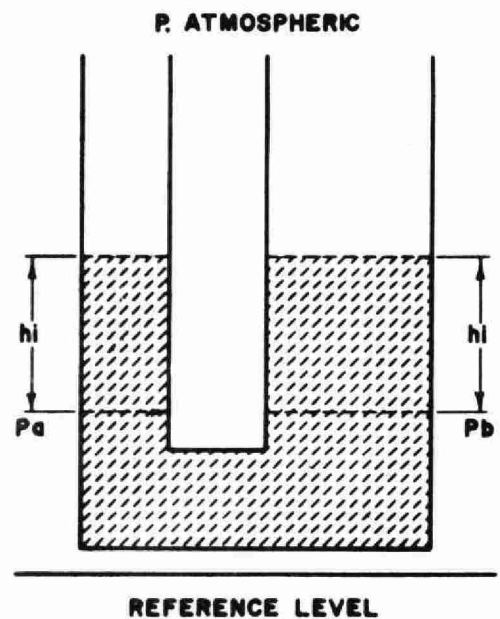
Instrumentation does require a trained technician to maintain the instruments in calibration and repair, however the principles of operation are simple and can be understood by the operator. This understanding will assist in determining the limitations of the equipment and what may be done in a particular problem. It must be remembered that all flow instruments are only accurate to 1% in the 20 to 80% range, 5% in the 10 to 20% and 80 to 90% range, and cannot be considered accurate below 10% scale.

It is not our intention to continue the 'little black box' theory in regards to instrumentation but to help disperse the mystery to allow the operation of the instruments to be of some importance to the operator.

DIAGRAM - I

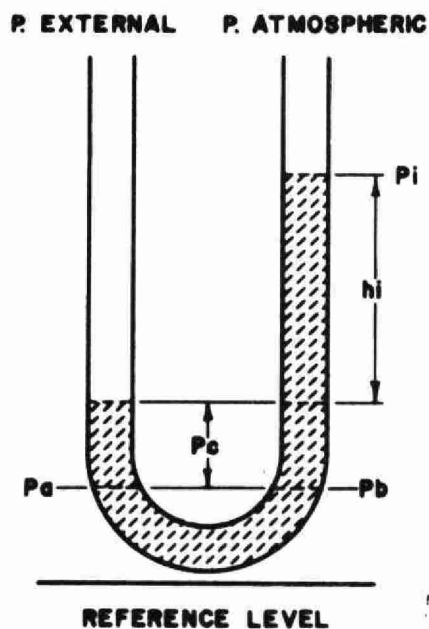


A



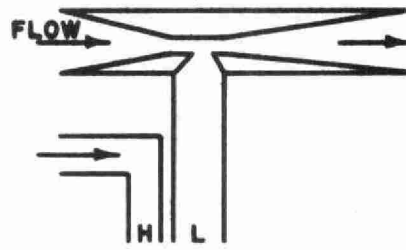
B

U-TUBE MANOMETER

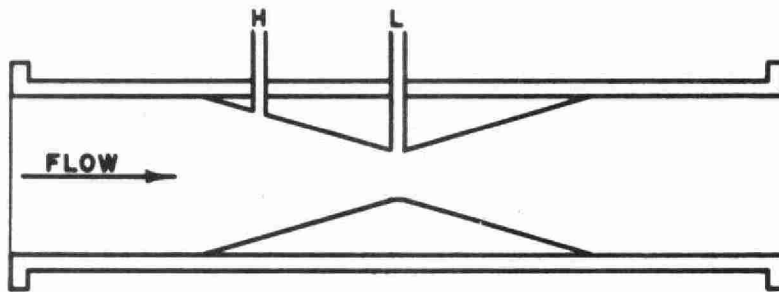


C

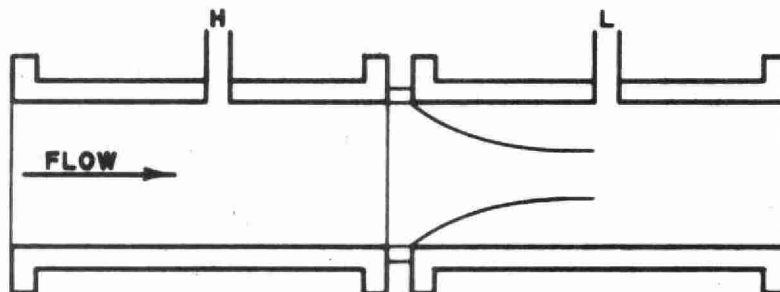
- A — PRESSURE BALANCE ANY SET OF POINTS OF EQUAL HEIGHTS ABOVE REFERENCE.
- B — PRESSURE EQUALITY OF POINTS AT SAME HEIGHT ABOVE REFERENCE INDEPENDENT OF SIZE OR SHAPE OF LEGS.
- C — PRESSURE DIFFERENTIAL SHOWS LIQUID RISES IN LEG SUBJECTED TO SMALLER PRESSURE.



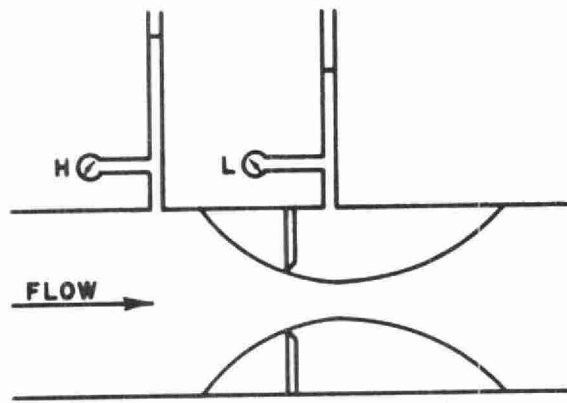
PITOT TUBE



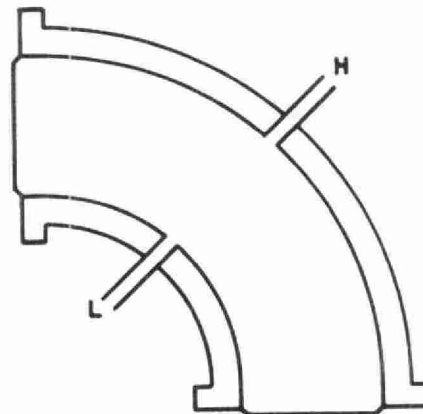
DALL TUBE



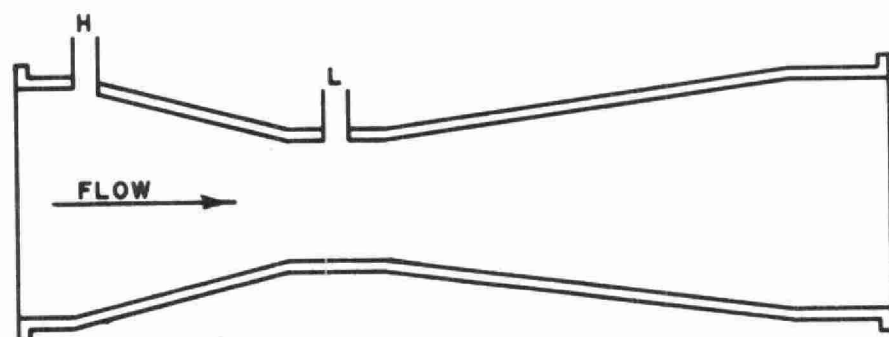
FLOW NOZZLE



ORIFICE PLATE

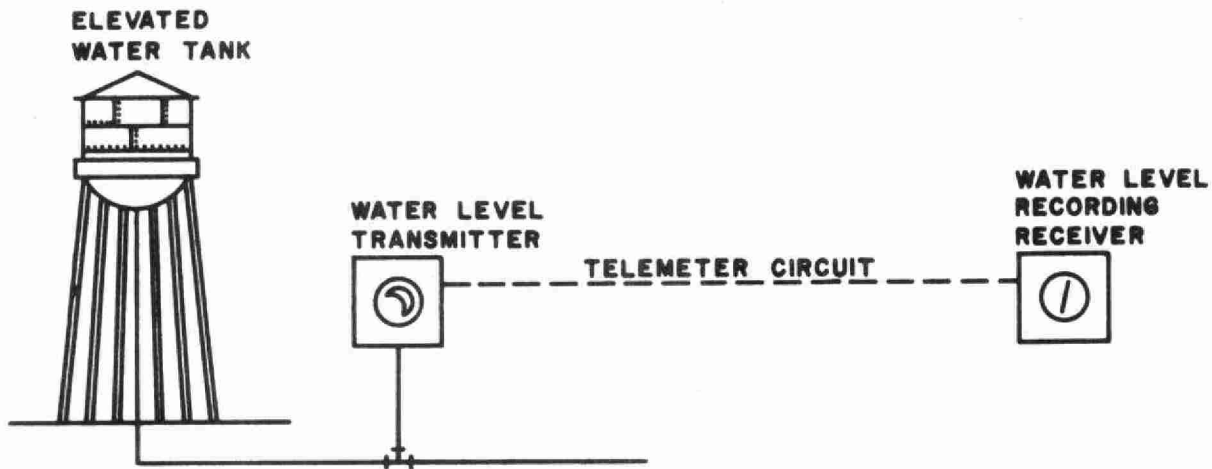


ELBOW METER

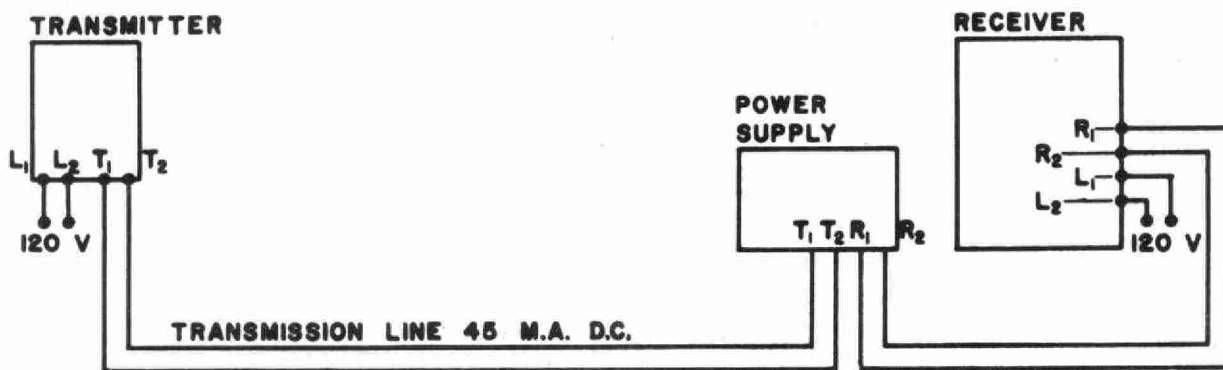


VENTURI TUBE

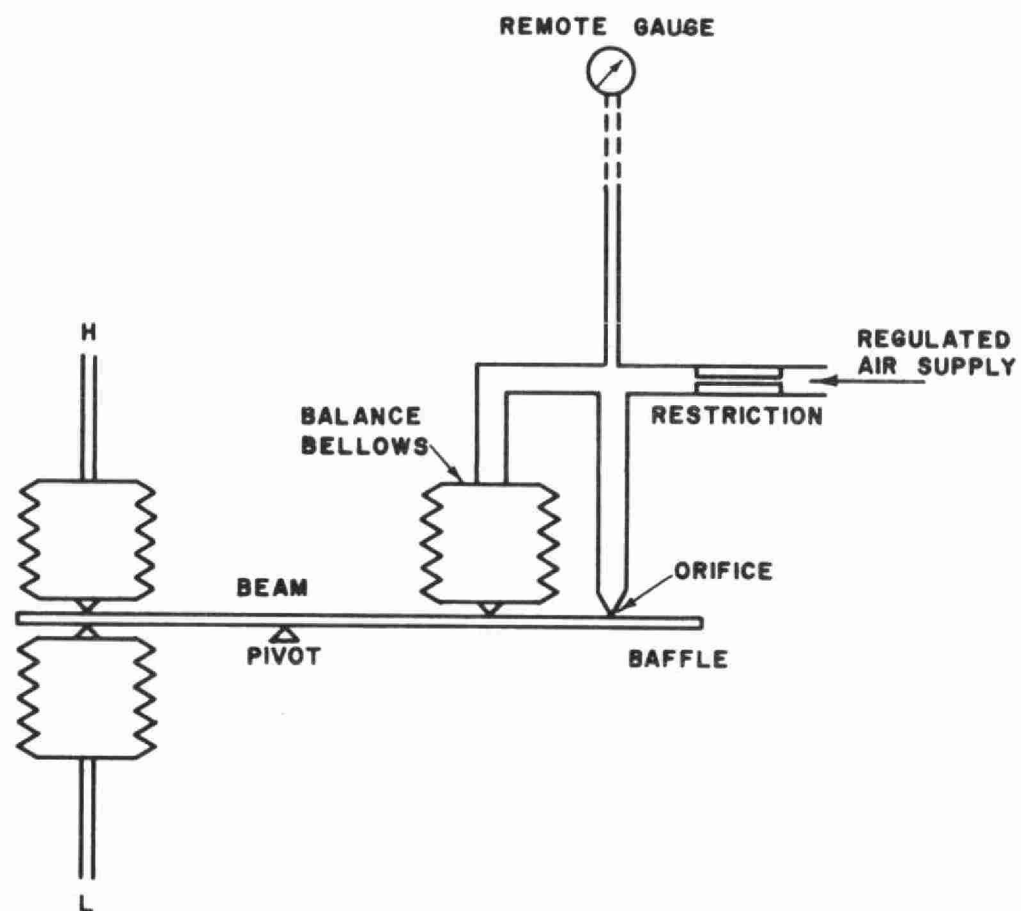
REMOTE MEASUREMENT OF LEVEL IN WATER TOWER USING ELECTRIC TELEMETER



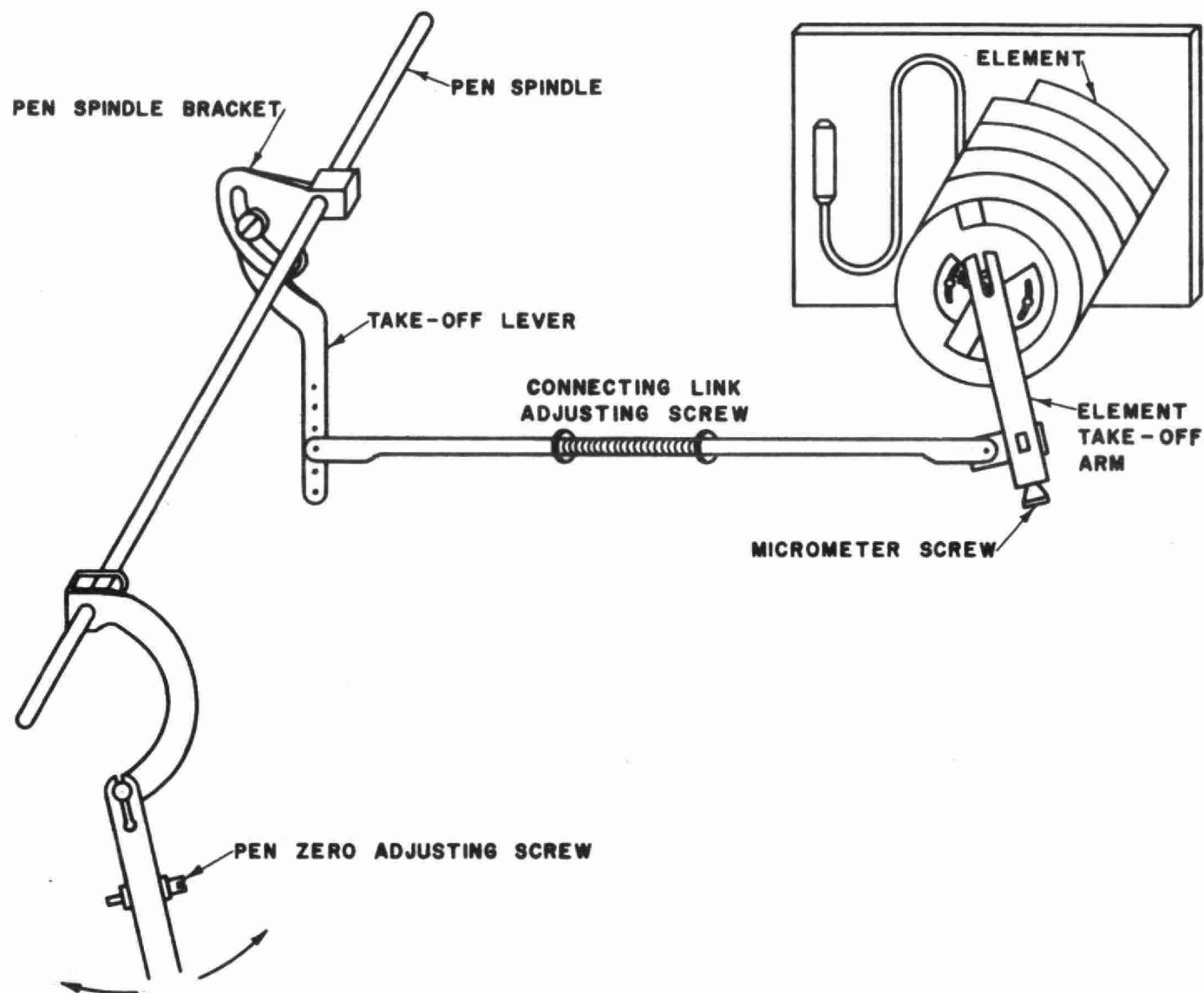
WIRING DIAGRAM OF TYPICAL METAMETER CIRCUIT

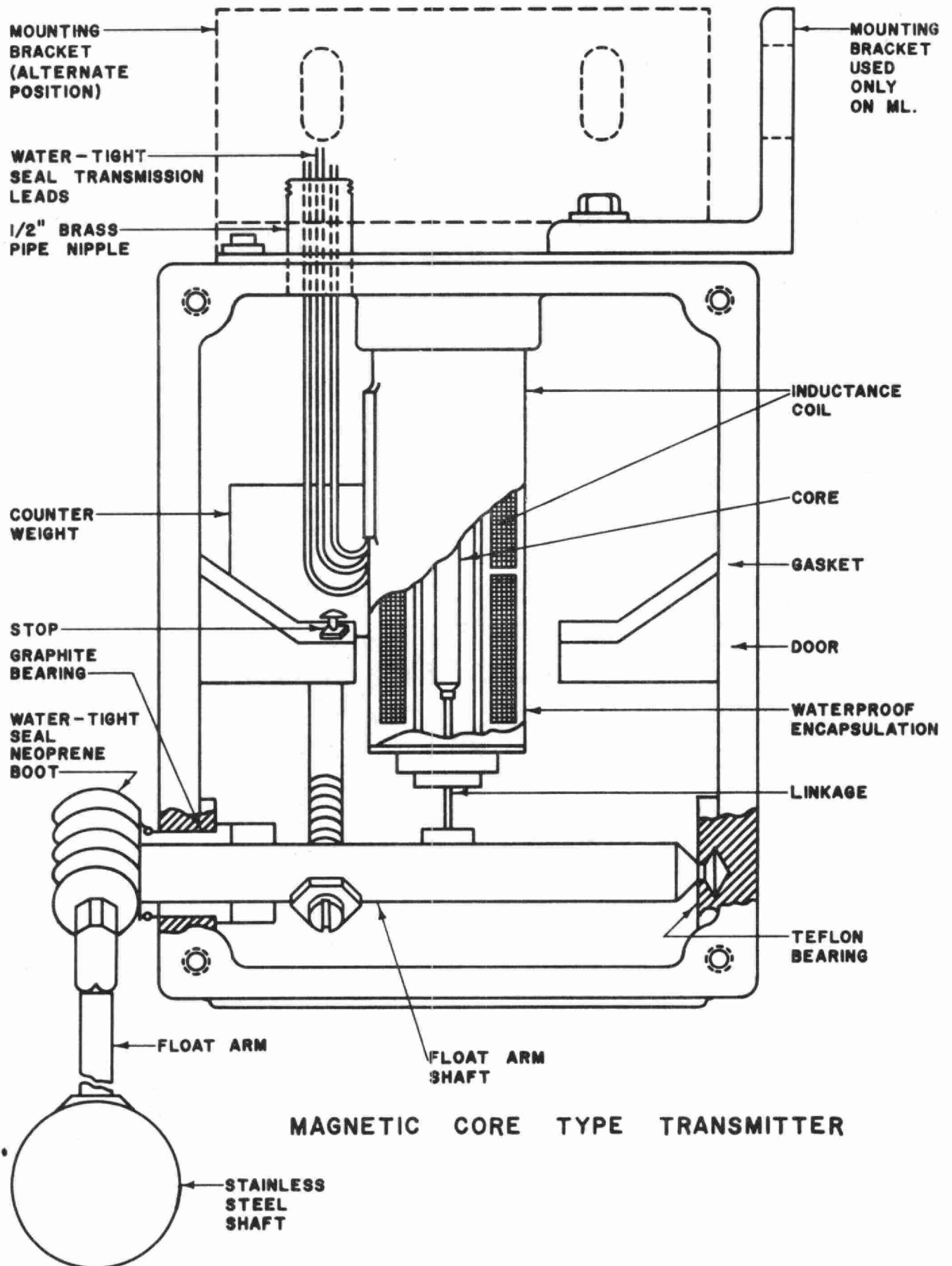


BELLOWS TYPE DIFFERENTIAL PRESSURE TRANSMITTER



BOURDON TUBE TYPE OF A DIFFERENTIAL TRANSMITTER





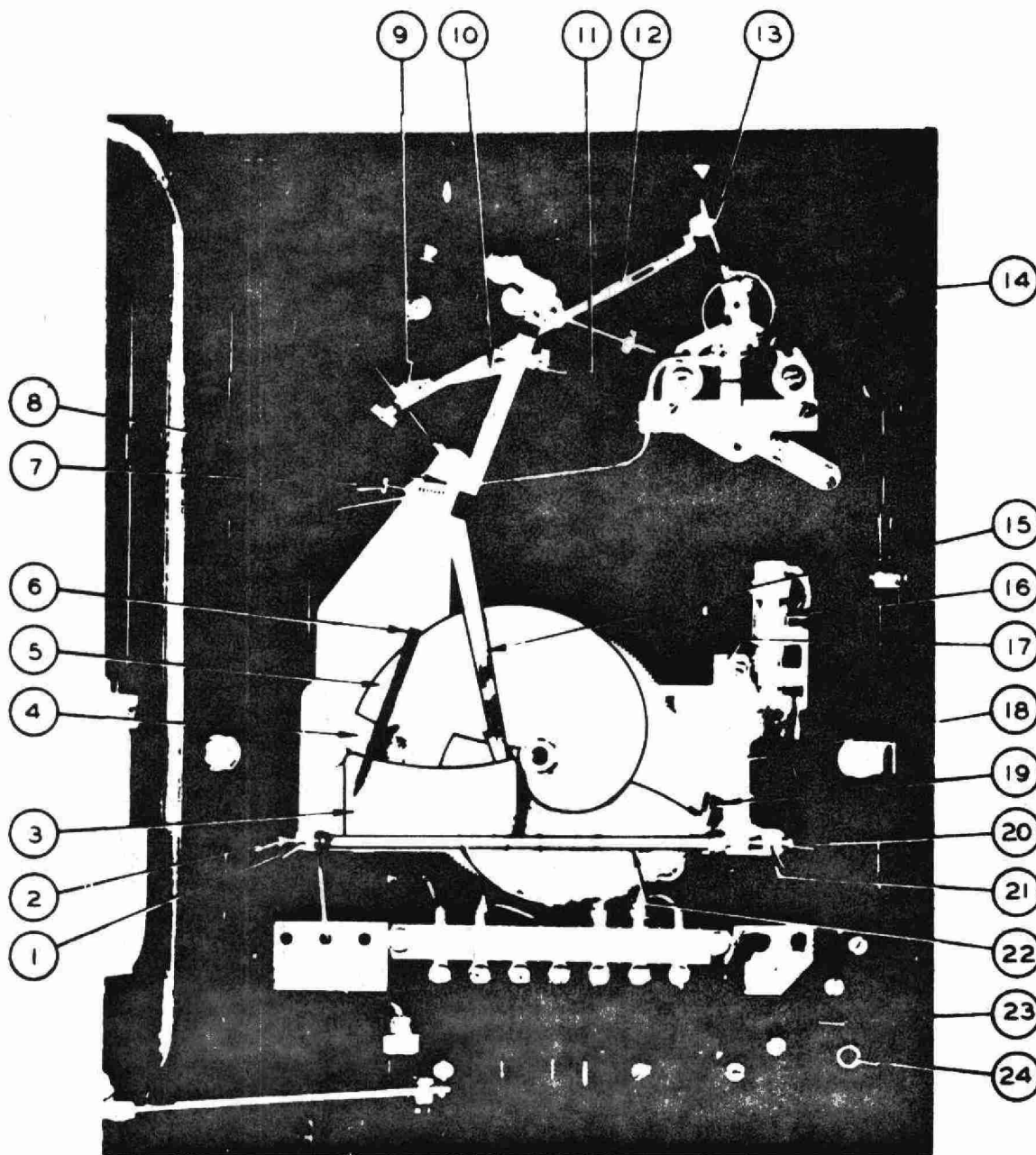
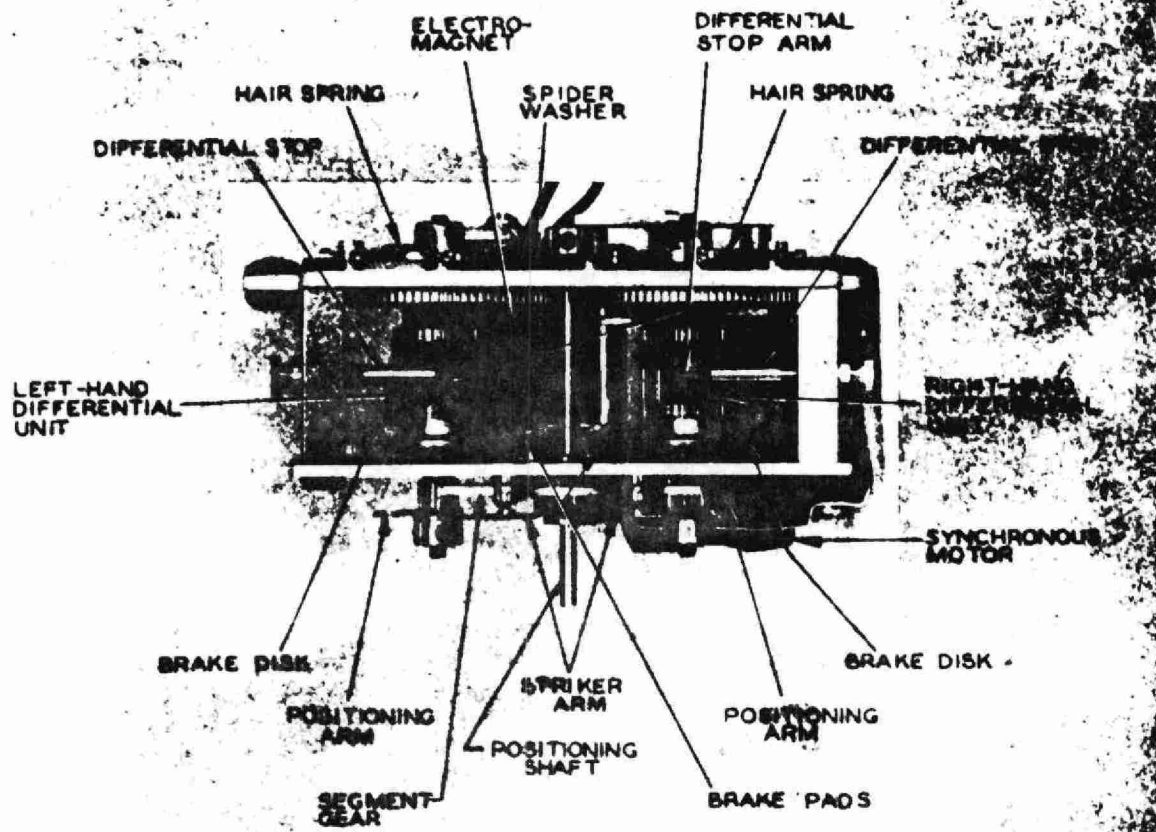


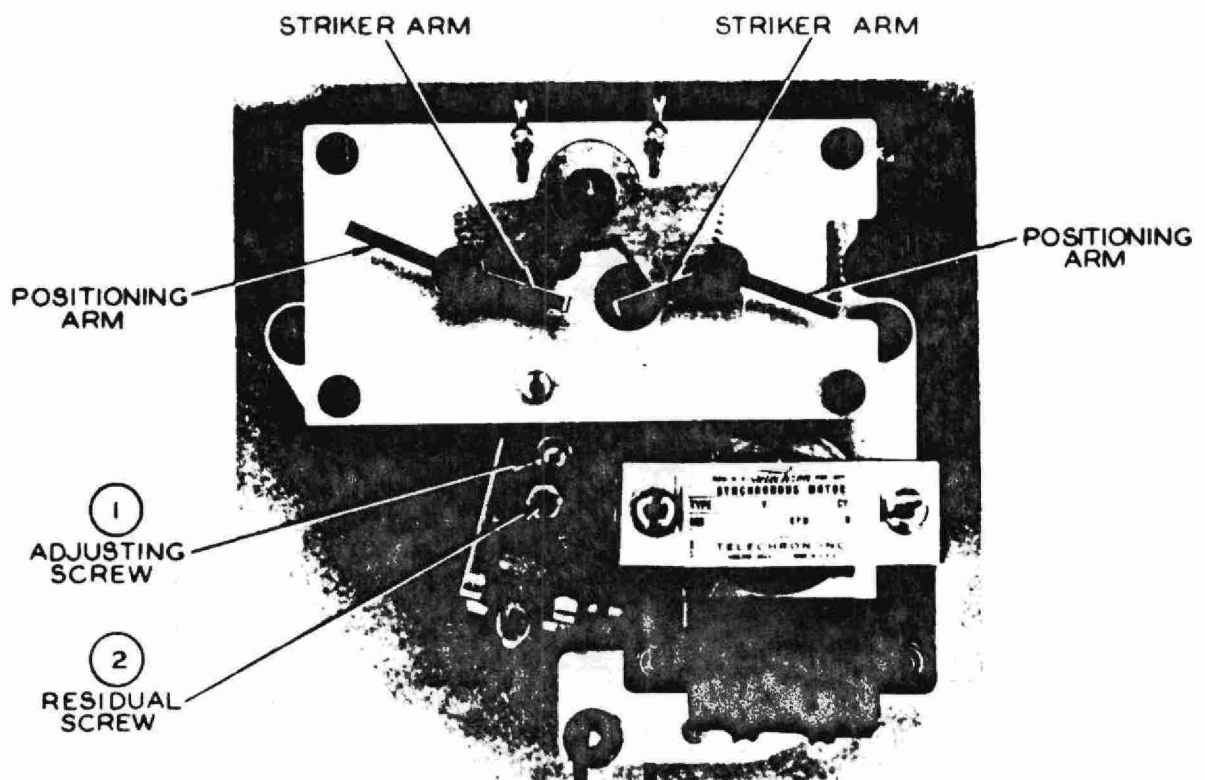
FIGURE 2. TYPICAL METAMETER TRANSMITTER WITH TIMER PLUG ATTACHMENT RI4A AND SCALE PLATE REMOVED

CODE TO FIGURE 2

- | | | |
|--|--------------------------------------|-------------------------------|
| 1. Locking Screw | 13. Span Adjustment for Cam Follower | |
| 2. Bearing Screw | 14. Measuring Element | |
| 3. Lifter Plate | 15. Cam Follower | |
| 4. Fixed Arm | 16. Mercury Switch | |
| 5. Cam | 17. Permanent Magnet | |
| 6. Indicating Pointer | 18. Vane-Arm Assembly | |
| 7. Zero Adjustment for Cam Follower | 19. Balance Cam | |
| 8. Locking Screw | 20. Bearing Screw | |
| 9. Span Adjustment for Indicating Pointer | 21. Locking Screw | |
| 10. Linearity Adjustment for Pointer | 22. Trip-Plate Shaft | |
| 11. Zero Adjustment for Indicating Pointer | 23. Convenient Outlet | } Attachment RI4A
Optional |
| 12. Linearity Adjustment for Cam Follower | 24. Timer Plug | |

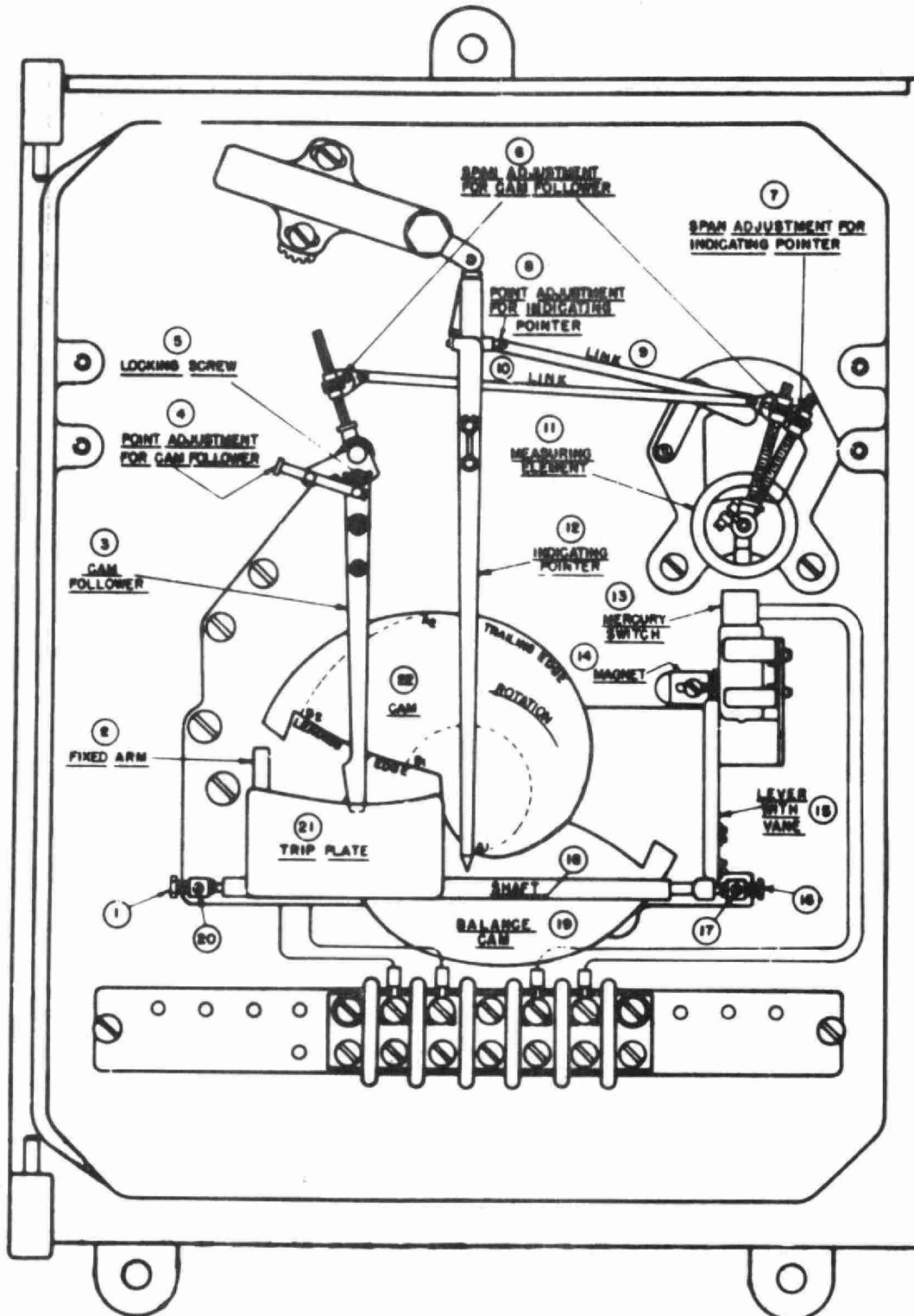


METAMETER RECEIVER MOVEMENT (TOP VIEW)

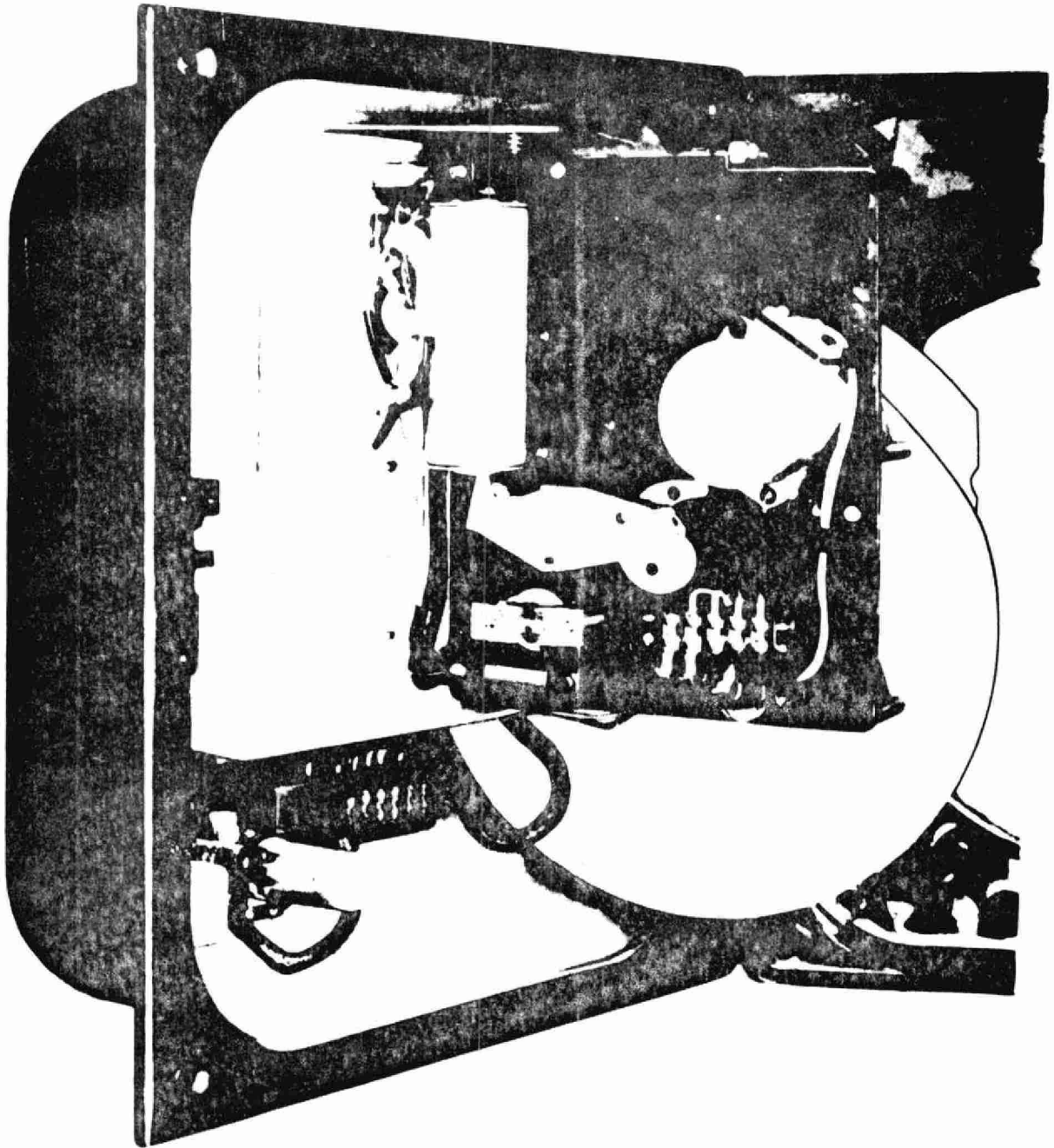


METAMETER RECEIVER MOVEMENT (FRONT VIEW)

CAM TYPE TRANSMITTER



MAGNETIC CORE TYPE RECEIVER



BUILDING AND GROUND MAINTENANCE AT PLANTS

A. Clark, P. Eng.

Operations Engineer,
Division of Plant OperationsINTRODUCTION

A prime requisite for any plant treating or pumping water, is that it be clean. There is an immense psychological value keeping a plant in a high state of cleanliness. Visitors do not expect a high standard of cleanliness in a plant and it is not unreasonable to assume that many visitors come in a critical state of mind. If your plant is clean, these visitors are pleasantly surprised. This is lesson 1 in public relations. Remember the quality of your product is measured by the appearance of your plant. Dirty plant, dirty product. Good plant, good product. We will discuss ways and means of creating this correct impression with the public. It will be discussed in two distinct parts:- Building Maintenance and Grounds Maintenance.

A - Building Maintenance

A large part of this is housekeeping. Cleaning should be done on a routine basis. Particular emphasis should be placed on office space, lunch room, washroom and locker room. Close attention should be paid to laboratory facilities and the control area. As well as being kept clean, these areas should be kept tidy. As a matter of fact, if you haven't time to keep the place clean, keep it tidy. Next in the order of importance are areas such as filtered galleries, pump rooms, chlorine rooms. Wherever possible, floors in these areas should be kept waxed and polished. A non-skid wax should be used at all times. A hospitalized visitor is not likely to be too complimentary. Keeping floor areas clean in the winter time is a problem, especially if the operator has to run in and out answering the telephone and fetching tools, etc., but it must be done. The floors can be protected by coconut matting paper or rubber runners in the main tracking areas. In the modern plant, an industrial type floor polisher is almost a necessity and, if you do not have one, you should make every effort to persuade your employer of the need for one. Next in the order of importance, and forgotten by most but the visitors, would be the window ledges, desk tops and shelving. These should

be kept clean at all times. Some visitors like to look in cupboards. Keep in mind that cupboards are for storage and not for depositing odds and ends in a haphazard fashion. There is a bonus to the operator in this, in that he knows where things are. Next on the list would be the windows. Windows are for two basic purposes:- one, to permit light to enter the building and two, to enable one to look out. When windows become dirty, efficiency in both these items is lost. It should be noted that when windows consist of two sides, inside and outside, both get dirty.

The operator can be aided in his cleanliness by routine painting and waxing. Scaling pipe never looks clean and an unwaxed floor is difficult to maintain. This waxing of floors can be carried one step further. In recent years, waxes have been developed for concrete floors and these waxes can be applied successfully in pumping station dry wells and basements of control buildings. The basic reasoning is sound. Any concrete floor will continually dust from the day it is poured. Dusting becomes worse as time progresses. The wax seals the concrete from the eroding action of the atmosphere. A good concrete sealer will have the same effect, but it will not shine up under polishing as is in the case of application of liquid wax. In one large pumping station, where the operator brushed the floor daily, he found that after applying proper wax and polishing that his maintenance was reduced to hosing down once per week. We now move on to the laboratory. Larger plants are now equipped with sizeable laboratories, and even the smaller ones have some designated area where testing is done. Glassware on counters and racks should be kept clean when not in use. Solvents are available for cleaning glassware.

Equipment painting is a subject by itself and this lecture will confine itself to the basic appearance rather than the protection aspect. The ground rules apply:

1. Do not paint over rust.
2. Do not paint over partially scaled paint, and if paint continually peels, find out why.
3. Paint work should almost always be cleaned with a stiff wire brush or sandblasted, wiped, primed and finished off with an application of finish coat.

There is a fairly general opinion that copper and brass fittings and piping should be burnished and not painted. If they are burnished, a light coating of clear varnish will maintain the appearance indefinitely.

Painting of concrete floor can be a risky business. What will give satisfaction in one plant gives heartache in another. However, concrete which has been well cured and has received a finished surface, receives paint readily and general appearance is satisfactory.

The following are a few tips for aiding cleanliness and easing operation. A simple wall rack for the storage of current magazines does much to improve the appearance. If your plant has a lunch room, dirty cups and cutlery should not be left around but should be washed and returned to storage after use. Lockers should be provided for street clothes and personal belongings and protective clothing should be stored on a rack close to an outside door.

If you have a workshop area, this should also be kept clean. Mechanics, although they take great care of their tools, tend to be untidy. They should be encouraged to clean up after extensive use of their workshop, put away dirty rags, sweep the floor and store bulk equipment neatly.

A word of caution here, if there is a janitor at your plant, do not try to make him into a personal servant. He has lots of work to do.

There are numerous side benefits from this public relations approach to cleaning. There are better working conditions for yourself, things are easy to find when you need them, and safety practice is made easier.

Still confining our discussion to buildings, we will examine what can be done to aid the appearance of the outside of the building with a minimum of additional effort.

When we discussed windows, we managed to get both sides clean so we will leave them now. Brickwork, when it becomes splattered with mud or simple rain soils should be hosed and occasionally brushed. It may be necessary, on occasion, to wash the brickwork down with muriatic acid, especially if efflorescence is the problem. Where vertical wood siding is used as an architectural feature, it is much easier kept oil than varnished. If you are not already keeping your tanks hosed and brushed, it is too late to mention them. However, here are a few thoughts on launders.

Launders can be painted with either a metallic or base paint. Good use can be made of ceramic tile, especially in white or pale colours. This is not as ridiculous as it sounds, because it makes your final or interim product appear much cleaner. Whatever your choice of paint or tile, they are much easier kept clean and, in many cases, a rubber squeegee can be used in preference to a wire brush. Hand rails around tanks should be kept clean and painted and lucky is the operator to inherit aluminum hand rails. In the larger plants, a steam jenny is a good investment. All this endeavour would appear to be time consuming, and it is, if you have to start from scratch, but the plant superintendent or chief operator who has had his plant spotless for an official opening will confirm the old adage that it is easier to keep a clean plant clean than to keep a partly clean plant looking partly clean.

B - Grounds Maintenance

Grasscutting

Area is the criteria. If you have a relatively small area, it can receive complete attention and be cut regularly. However, if you have a large area, you can go broke on cutting grass alone. Let us consider a small area to consist of one acre or less. Here there is no problem since an area of this size can be kept close trimmed and weeded at all times. A word of caution here. Do not cut your grass too short in summer time, since all you will do is burn it out. Where you have larger areas, in many cases, up to ten or more acres, the operator does not have the time nor staff to keep the entire area in bowling lawn condition. Where this is the case, attention should be concentrated on the area adjacent to buildings, tanks and access roads. This area should extend some 25 to 50 feet beyond buildings and tanks, and in the case of access roads anything up to 25 feet on either side of the access roads clipping the ditches should be kept trimmed and weed free at all times. Grass beyond these areas should be kept reasonably short and cut down when it grows to or reaches the height of approximately six inches. These fringe areas should not be watered and, in this way, the grass will remain green and it might be possible to cut no more frequently than once every two weeks. These fringe areas in most plants would extend to the fence line or even beyond. At many plants, property beyond the fence is owned and, if this is a field, consideration should be given to renting out or lending to a farmer.

Lawn-cutting Equipment

Much has been said on this, and much will be said, and it gets down to the matter of individual choice; however, here are some basic guide lines. For steep banks around tanks or steep contouring, a small two cycle mower is a must. It is also handy for ducking in and out of flower beds. On the larger, flatter areas, a large rotary four cycle mower is more desirable, something of the size of a 7½-10 H.P. Gravelly, either walking or riding. The thing to look for here is a wide cut, 54" and more is now possible with double sweep rotary blades. This will handle most of your grasscutting and will cut the working time substantially. If your plant is located in what looks more like an estate than a piece of property, large farm type tractor type mowers should be considered. Although they are expensive, they will eventually pay for themselves and save time and labour.

Landscaping

The immediate building area extending 25 to 50 feet beyond the buildings and tanks should be landscaped. As previously mentioned, grass should be close cut and weeded. But again, a word of caution, do not cut grass shorter than an inch and a half. In this way, the grass develops a strong root structure and will choke out weeds by natural process. The use of gravel or crushed stone adjacent to the tanks is serviceable, but mainly to the growth of weeds in the gravelled area. This can be overcome by laying slight gauge plastic under the stone. Lawn areas are the most attractive and eye-catching, and these should be kept clear of weeds as previously mentioned. There are numerous selective weed killers on the market and the operator has a wide choice of what he wants to kill. In this he is free to kill everything but the grass.

If water is available, the area immediate to the building and tanks should be kept watered. However, during periods of summer water shortages, it does not look good for the plant to be using water, when everyone else is on restrictions. This will nullify your public relations.

Access roads, pathways and driveways are frequently neglected, often through no fault of the operating staff. It is impractical to have a gravel driveway on which trucks are making several daily trips. After several years of this operation, the access road assumes the appearance of a rutted cow path and very little can be done except regrade it. Under these circumstances, lightly travelled roads should be oiled and heavily travelled roads should be paved.

Flower beds enhance the plant appearance, but are time consuming and should be kept to a minimum and restricted to locations where they immediately catch the eye. In planning flower beds, do not restrict the flowers to one space. Arrange them so that there is a group of flowers in bloom throughout the summer season. Perennials frequently require less attention and less financial outlay than the annuals. Trees and shrubs should receive close consideration especially beyond the immediate landscaped areas. Trees have three basic functions: windbreaking, screening and sun shade. As you all know, there are two basic trees in this area:-

- a) coniferous
- b) broad-leafed

a) Coniferous trees would be -

1 - Eastern White Pine - which is a tall, stately tree and can reach a height of 175 feet with a trunk diameter of five feet, but this is unusual and it is usually 100 feet or less in height and no more than three feet in diameter. This tree will grow on wide range of sites from dry, sandy to bogs, but it does best on a moist sandy soil.

2 - Red Pine - Its average height is 100 feet with a trunk diameter less than three feet. It grows best on a loamy sand or gravel but can thrive just about anywhere.

3 - Tamarack or Juniper - This is a medium size tree, 60 to 70 ft. high, with a trunk diameter up to 2 feet. This tree grows best in damp, swampy areas.

4 - White Spruce - This can grow to a height of 120 feet with a trunk diameter of four feet (usual height is 80 feet). This tree grows best in well drained moist soil close to streams.

5 - Hemlock - This is a medium size tree, growing to some 60 to 70 feet in height, and up to two feet trunk diameter. This will grow just about anywhere.

6 - Balsam Fir - This also is a medium size tree, and it will grow just about anywhere.

b) Broad-Leaf Trees

1 - Aspen or Poplar. The average height of this tree is about 40 feet with a trunk diameter of about 8 to 10 inches. This tree grows best on a well drained loam and is found almost anywhere.

There are other broad-leafed trees, some of which are:-

Walnut, Hickory, Iron Wood, Birch, Beech, Oak, Elm and Maple.

I have mentioned only a few of the possibilities. There is an infinite variety of trees, but the ones that I have mentioned are readily adaptable to Southern Ontario climates and the Evergreens, of course, will grow to the far North of Ontario. Operators with plants on the North shore of Lake Superior should take the advice of the local Forest Ranger. Broad-leafed trees should not be planted adjacent to tanks or they create a leaf problem in fall, with subsequent plugging of pipes and pumps.

Those operators with small plants will not be able to go into the tree growing aspect and should consider instead, the growth of shrubs. Here again, climatic conditions prevail, but there are numerous Evergreen shrubs that can be grown easily in Southern Ontario.

LAWNS

I MATERIALS AND TOOLS

1 - Humus and fertilizer - Any texture of soil will suffice in a pH of between 6 and 7 if necessary. Starting with 50 lbs. of fertilizer per 1,000 sq.ft. - first year - it should be fed at the rate of 20 lbs. per sq.ft. per year, preferably in March, April and September.

2 - Grass seed of good grade in a mixture suitable to soil and light conditions. Quantity -- about 4 lbs. per 1,000 sq.ft. Tools and machinery -- a Roto-tiller; spade, if the work is to be done by hand; iron rake; baskets, wheel barrow, roller or tamper and a hose.

II PROCEDURE

(a) Building a New Lawn

1. Choose the most opportune time to sow seed. Early fall, late August or September is best, with early spring as a second choice. Rye grass or Timothy can be sown temporarily - to be ploughed or dug under later, or sodding may be resorted to - although it costs twice as much as seeding.
2. Prepare the seed beds some weeks in advance so that it can settle before sowing.
 - (a) Test soil to find out if lime is needed and how much (check the pH)
 - (b) Plough or Roto-till the existing soil. Remove stones and debris and rough grade before preparing the seed bed.
 - (c) Replace any top soil which may be piled to one side of the lot during rough grading for drainage, etc.
 - (d) Spread (all at one time, if desired) any necessary lime, commercial fertilizer, humus, and mix them with the top six inches of soil by Roto-tilling or digging at least a week in advance of seed sowing.
3. Other good grades of lawn seeding have a mixture which suits soil and light conditions. If the grounds are in part shady areas, then a shady mixture may be sown throughout. If both sunny and shady mixtures are being used, grade the two together where they meet to avoid the deciding difference in grass texture.
4. Add more fertilizer to the surface inch or two, rake it in and smooth down the surface just prior to seed sowing.
5. Sow the seed in two directions, first splitting the quantity equally.
6. Rake the seed into the soil very lightly after sowing and firm the bed with a light roller, if available, or a tamper.
7. Water with a spray mist if drought sets in before the seed sprouts well. Supply ample water throughout the first season.
8. Begin to mow when the grass reaches a height of 3 or 4 inches. Set the mower to mow the new grass at $1\frac{1}{2}$ inches in height.

9. Destroy crab grass and other weeds when they appear. Do this by hand the first season as chemicals would be too strong for new grass.

10. Follow through every year by feeding and top dressing in the spring or fall and by keeping the grass as weed free as possible.

(b) Renovating an Existing Lawn

If a lawn has a stand of 1/3 or more of good grass, it is worth renovating. The following method can be used to improve a new lawn of poor thin soil, or an old lawn which has become crab grass infested.

Early fall is the preferred time to renovate, otherwise early spring.

1. Mow the grass short first, then rake off the clippings along with the fallen leaves, dead crab grass and other weeds.
2. Feed the whole lawn with a special lawn fertilizer or general commercial fertilizer.
3. Scratch all the bare patches of soil with an iron rake.
4. Seed them with a good mixture by hand and rake in very lightly.
5. Using a light roller or tamper, compact the soil.
6. Keep the surface soil moist by watering both before and after the grass shows above ground.

Now in conclusion: We have not covered the entire field. The purpose of the lecture was not to tell you what to do and when to do it, but rather, to make you see the overall problem and plan your attack accordingly.

DISTRIBUTION SYSTEM MAINTENANCE

R. Peacock,

Water Works Superintendent
Oshawa Public Utilities Commission

INTRODUCTION

Maintenance comprises those operations which serve to keep a system functioning properly. Repairs, on the other hand, are those steps taken to replace broken or worn parts of the system. Since these two terms are not given the same meaning by everyone, we shall use the term preventive maintenance to mean ways of keeping a system functioning without costly breakdown. The term corrective maintenance will be considered to include those operations required to repair or replace any part of the pipe system.

MAIN LINES

Adequate maintenance of any part of any system requires a supply of proper tools, equipment and repair parts. The tool supply should include pumps, cutters, wrenches of all types, air tools, caulking tools and various kinds of small hand tools. When a large line is cut or broken, the best available pump should be used. Diaphragm type pumps will be found to be most satisfactory when the water to be pumped contains large quantities of sand or clay, which tend to clog and cause premature failure of seals in centrifugal type pumps. If a large volume of clean water is to be pumped quickly, centrifugal type pumps are the best choice. Caulking tools are needed when lead joint pipe is used in the system. Air tools save valuable time when it is necessary to cut through a paved road. Various types of pipe cutters may be used, but when it is necessary to remove a section of pipe, it is handy to use a cutter such as the Strickler ratchet cutter which removes about 1/8" of the pipe allowing easy removal. It also helps to eliminate the danger of breaking the pipe which is to remain in service. In making any cuts in a pipe, it is important to cut only as much as required and, if possible, to make all cuts square which enables better joints to be made when fittings are installed.

Various other types of equipment are used which help to save time and money during repairs. There are for example, two way radios which cut down the number of men required to maintain the system; leak detectors which have the obvious advantage; pipe locators of all kinds are used for spotting underground pipes, and where there are many underground lines, a special wireless electric locator is used; a valve box locator, which is no more than an inverted compass which will pick up almost any metal such as valve boxes, meter boxes or sewer manholes, and is especially handy in case of emergency.

A good supply of repair parts is important as any repair job can be costly if it has to be patched up until the parts are available.

Road reconstruction is causing us to be involved in some of our biggest corrective maintenance jobs, involving relocation, lowering and offsetting of existing water mains, hydrant connections and services to accommodate new road grades, sewers, etc.

When lowering a line, it should be let down slowly and the offset in each joint kept the same. Care should be taken that the deflection in each joint not be permitted beyond the maximum limit. As an example, when lowering an eighteen foot length of eight inch diameter cast iron mechanical joint pipe, never let any such length of pipe deflect more than 20". The maximum allowable deflection for any pipe or joint size can be found in the manufacturers' handbook. If the pipe being lowered has lead joints, it is necessary to recaulk each joint.

If an offset in a large line is to be made with bends, it is recommended that straps be used to hold the bends in place. All bends must be firmly blocked before the water is turned on, as any pressure surge on an unsupported bend can blow the joint apart. An offset is usually made by joining two similar bends with a short section of pipe.

Many kinds of fittings and repair parts are used in line repairs, and a few of them are listed here.

The split sleeve can be used for repairing broken or split pipe. There is a special kind of split sleeve made for repairing broken bells. This sleeve may also be used for joints in which the spigot end has moved out of the bell. When repairing a section of pipe that needs several lengths, the pipe can be replaced and the last two pieces can frequently be raised and "buckled in", thus saving a sleeve.

Corroded or broken steel pipe can usually be repaired with a flexible type coupling.

Asbestos-cement pipe can be repaired by using sleeves and adapters manufactured specifically to fit this pipe. The suppliers can also provide special short lengths of asbestos-cement pipe with machined ends, and short machined overall lengths are available to eliminate some of the field operations required to repair this pipe.

GATE VALVES

In a new system, the maintenance of gate valves is limited mostly to the repair of stuffing boxes and valve boxes. There are also always cases where the valve is damaged, but with careful installation this should be at a minimum. In such instances, it is necessary to replace the broken part. Valve stems, gates, wedges or other parts can often be repaired with the body of the valve still in the main line.

In every system there is the need for periodic valve inspection. This is done to find valves that are closed or have some minor defect. Left-hand valves should be clearly marked if not replaced. Valves on 12" and smaller mains should be operated at least every three years and more often if the water being transmitted is of an aggressive nature. Valves larger than 12" should be operated at least once each year.

When a valve is closed, and water still passes the gate, the valve should be opened just enough for water to pass under the gate. This usually washes out anything that is stopping the gate from closing properly. If the gate is not effective after several repetitions of this, the gate should be removed from the valve. Any obstruction below the gate can be removed, and any worn parts replaced.

Some valves are hard to close and occasionally too much force is applied to them. When the gates are tightened down too much, they are sometimes warped and thus water can pass above the gates. The stem can also be twisted which will cause the gates and threads to bind.

A record showing the accurate location of every main line valve should be kept. This should be detailed drawing showing measurements from various permanent marks or objects, e.g. property lines, manhole covers, catch basins, fire hydrants, curbs and sidewalks.

The three intersection drawings illustrate the detail required to make these records useful. If intersection drawings are carefully drawn, using up-to-date accurate information, they will become most useful tools. The principal advantages of having these records readily available are:

1. They help to isolate main breaks quickly, thus reducing road and flooding damage.
2. They improve your public image by helping to avoid the seemingly endless search for that elusive last valve at an intersection.

Valve boxes should be kept up to grade at all times. Some may have to be adjusted several times, but in the event of an emergency, it is important to be able to locate valves quickly.

HYDRANTS

Of all the points of maintenance in a distribution system, hydrants could be one of the easiest, if a little preventive maintenance is used when the hydrants are installed.

One of the major problems in larger cities and towns is to find locations for hydrants away from potential traffic damage. In cold climates with severe winters, it is very important that hydrants be pumped out immediately after use to prevent freezing and cracking.

A suggested procedure for hydrant inspection is as follows:-

1. Use a sonascope and listen for underground leaks.
2. Check gate valve and valve box.
3. With the caps on, open the foot valve and check the stuffing box and nozzle caulking.
4. Close the foot valve, remove the caps, and check the drain.
5. Flush the hydrant.
6. Check and grease the threads on the nozzles and caps.
7. Check obstructions to use.
8. Oil the operating nuts.

Except for water storage tanks and valve boxes, fire hydrants are usually the only visible parts of a water system. It is, therefore, important that the exterior finish of hydrants be kept in good condition.

Some municipalities have adopted the practice of colour coding hydrants to indicate the amount of water available from each individual hydrant.

SERVICES

Curb stop boxes require periodic maintenance, particularly to follow up reports of boxes protruding above walkways. All reports of projecting curb boxes should be investigated quickly and necessary repairs should be carried out, before a pedestrian injures himself by tripping over the box.

When repairs have to be carried out on curb stops or pipe joints on the service ahead of the stop and waste valve, the flow of water from the main can be controlled by shutting off the main, which usually involves shutting off service to many customers, or the flow can be stopped by using one of several methods of temporarily freezing the service.

METERS

The most important and most obvious requirement of a meter is that it should register all flows accurately. Actual tests carried out on inaccurate meters showed that a high percentage would not register low flows. It was also shown that in most residential areas, about 27 to 54 per cent of the total consumption is at flows of less than 0.5 gal./min. Thus, for an economic production and distribution of water, accurate figures of consumption to be applied to water bills must be maintained.

In some systems a time limit plan is used, such as five, seven, or ten-year plan. The seven year plan is about the average for most systems and they usually start off by pulling all meters out of service that have been in use for seven years or longer. The time limit plan is not always effective when, for example, the water being metered is non-active and non-corrosive so that a large percentage of meters become inoperative from broken registers. In such cases, it is better to check the meter readings monthly, from which it can usually be determined if inaccuracies are apparent.

TANKS

The life of a tank depends upon a thorough and regular inspection, and prompt repair of it when repairs are necessary. Another item that determines the life of a tank and supporting tower is the type of water and weather conditions. The regularity of inspection depends on the type of system used and its location.

Tank inspections should be made after every storm and flood. Regular inspections are usually made in the spring of the year to allow plenty of time for repairs during the good weather.

The inspection is made to determine the extent of pitting or paint failure by blistering, peeling, rusting, or abrasion. The inspection report should state whether or not the pitting is in spots and can be repaired by welding, or whether the pitting is general and requires new sheets or structural members. The inspection report should contain as much detail as possible on the condition of the tank and any recommendations for repair.

During the inspection of the tank, the utmost in safety measures should be put into practice, because ladders and spider rods are usually the first to deteriorate.

CONCLUSIONS

We in the business of "manufacturing" potable water too often forget that the eventual target of our endeavours is the consumer, whether domestic or industrial. Bearing this in mind, it must be obvious to us that our efforts in the pumping station or filtration plant, our calculations and measurements on chlorine feed rates and micro-strainer operation comprise the first step in reaching our target. The second step is the care and maintenance of the distribution system which is equally important, for without due consideration to this, our other activities can be almost meaningless.

Let us consider the factors involved in the distribution system which affect our final target. If leaks in the distribution system go undetected, our consumers suffer through decrease in water pressure. We and the municipality suffer through loss of water, and again the consumer suffers either through paying higher rates for water, or higher taxes.

Where breaks occur in the system and proper cleaning and sterilizing is not carried out during and after repair, then the consumer suffers with water which may be contaminated or have a taste, odour, or colour. The bad publicity and possible health hazard from such occurrences are certainly undesirable.

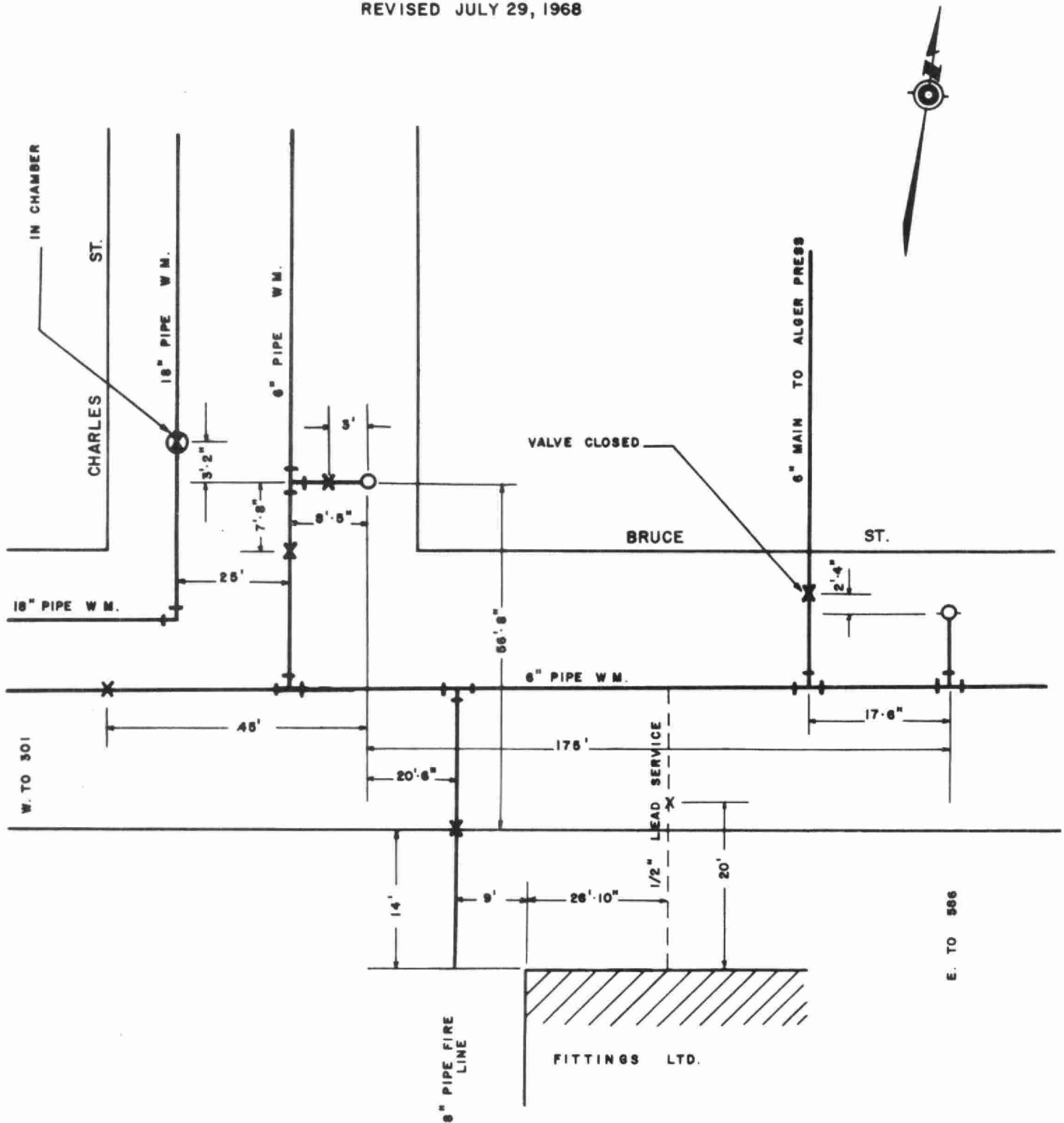
Neglect of the simple valve can cause extreme inconvenience to the consumer in the event of a line break, where it is necessary to close off much more of the line during repairs than is absolutely necessary.

Care and maintenance of meters should be rather obvious to ensure that no consumer is billed for a greater quantity of water than was actually consumed and conversely, no consumer is using more than he is paying for.

From this discussion, it can be easily seen that taking our starting point from the careful installation of an intelligently designed system, it is quite simple and relatively inexpensive to maintain the distribution system satisfactorily.

BRUCE ST. — CHARLES ST.

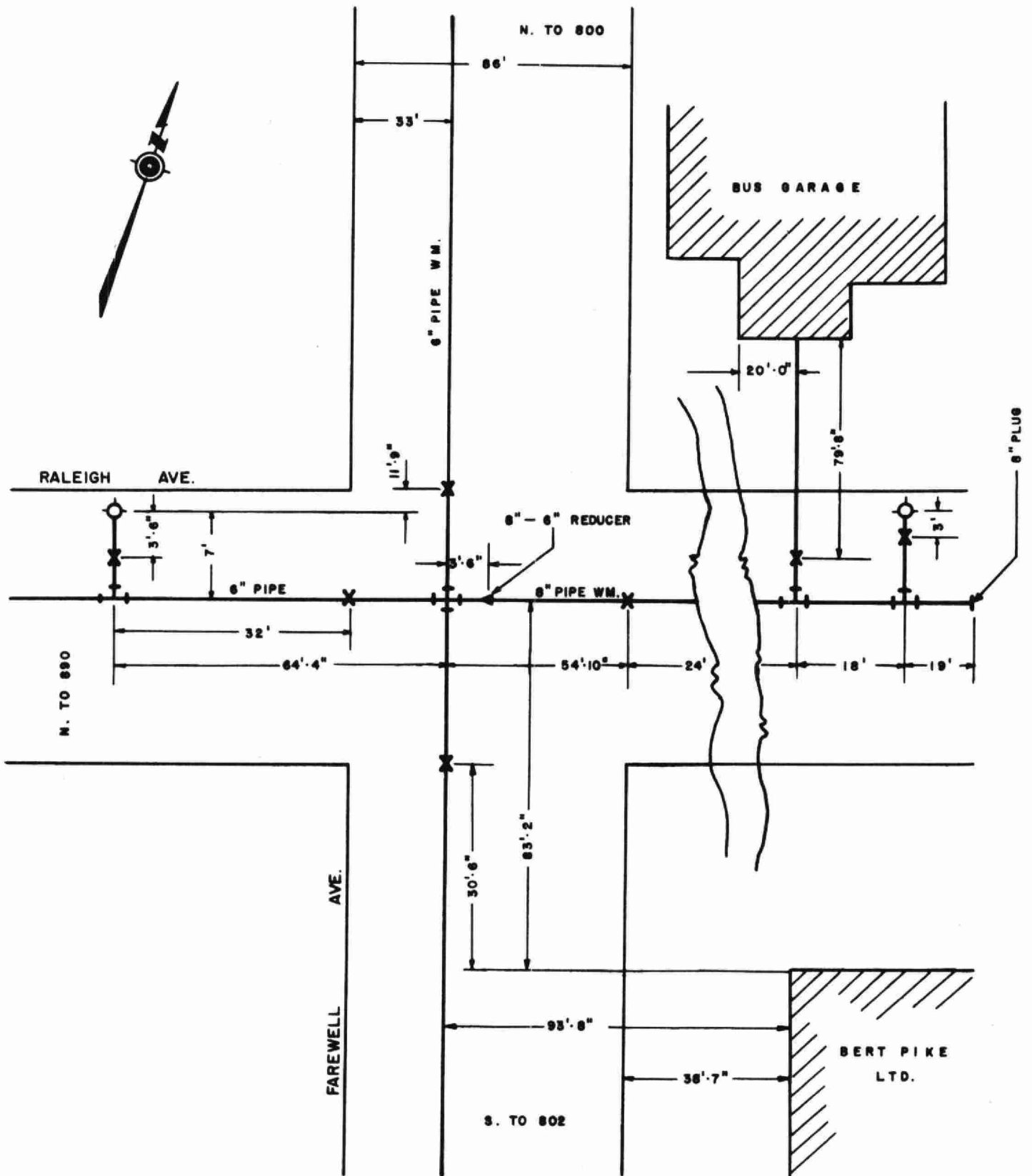
NOT TO SCALE
REVISED JULY 29, 1968



FAREWELL AVE. & RALEIGH AVE.

NOT TO SCALE

APRIL 25, 1962 REVISED AUG. 4, 1965



This engineering plan view illustrates the intersection of McLaughlin Blvd. and Simcoe St. The drawing includes the following details:

- Streets:** Mc LAUGHLIN BLVD. runs horizontally across the top, and SIMCOE ST. runs vertically through the center.
- Intersecting Street:** GRETA ST. branches off to the right from Simcoe St.
- Utility Lines:**
 - 8" PIPE W.M. (Water Main):** Shown as solid lines with 'X' marks at manholes. One runs horizontally along the top, another runs horizontally along the bottom, and a third runs vertically along Simcoe St.
 - C.S.W. (Combined Sewer):** Shown as shaded, hatched areas. These lines follow the curves of the streets and connect to manholes.
- Manholes:** Indicated by circles with a cross inside. They are located at various points along the water main and combined sewer lines, including at the intersection of the streets.
- Dimensions:** Numerous measurements are provided in feet and inches, such as 33'-9", 31'-10", 17', 18', 66', 26'-5", 20', 12'-6", 2'-8", 7'-1", and 17".
- Other Features:** A PORCH is shown at the top left corner. A north arrow is located in the lower-left quadrant, pointing towards the upper-left.
- Boundaries:** W. TO 401 is marked on the left, and E. TO 490 is marked on the right.
- Orientation:** N. TO 150 is indicated at the top, and S. TO 147 is indicated at the bottom.

CHLORINATION - PART I

G. R. Trewin,

Assistant Director
Division of Sanitary Engineering

INTRODUCTION

The basic lecture on chlorination will review the subject under the following headings:

Purpose of Chlorination
Chlorine Chemistry
Bactericidal Effectiveness; and
Chlorine Residual Determination

The lecture at the next course will delve further into the subject under the following five headings:

Types of Chlorine Residual
Equipment
Routine Operation
Emergency Operation; and
Adverse Bacteriological Results

PURPOSE OF CHLORINATION

The chlorination of public water supplies represents the most important process used in the production of potable water. The first and basic reason for chlorination is to provide disinfection. Disinfection refers to the reduction of the bacterial population to a safe level and the elimination of pathogens as contrasted to sterilization, which refers to the total destruction of the bacterial population.

The object of disinfection is to kill disease-producing organisms which may have gained entrance into a water supply. The bacteria involved are primarily those causing intestinal (enteric) diseases such as typhoid, the paratyphoids, and dysenteries; most other harmful bacteria are not generally considered to be spread by impure waters.

In addition to bacteria, viruses are now being given consideration. It is now believed the virus which causes infectious hepatitis can be water transmitted. In the same regard, the poliomyelitis virus may also be of importance.

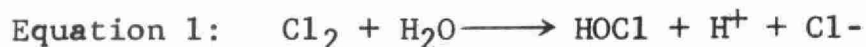
CHLORINE CHEMISTRY

The reactions of chlorine with water and with the many substances that may be in the water and the effect temperature and pH have on these reactions are all related to the performance of the chlorine added.

There are a tremendous number of reactions that can be initiated when chlorine is added to natural waters. It would take considerably more data than we now have to predict exactly what will take place when chlorine is added to the water.

To simplify the ensuing discussion, the majority of materials with which chlorine will react in dilute solutions will be roughly categorized into five groups: inorganic substances, ammonia, amino acids, proteins, and carbonaceous matter.

The first reactions that should be considered are those between chlorine and water (equation 1 and 2). In chemically pure water, chlorine reacts with the water and hydrolyzes to hypochlorous acid (HOCl) and hydrochloric acid (HCl).



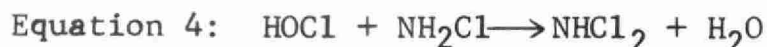
When the pH is above three and the concentration of chlorine is less than 1000 mg/l, the reaction is, for all practical purposes, irreversible and instantaneous. The hypochlorous acid dissociates to hypochlorite ions (OCl-) and hydrogen ions (H⁺). The equilibrium condition for this reaction is a function of the pH and temperature as shown graphically in Figure 1. Because the dissociation is so rapid, the equilibrium ratio at any given pH remains constant even though the hypochlorous acid concentration may be decreasing.

Since the oxidizing agents in water are the hypochlorous acid and the hypochlorite ion rather than molecules of elemental chlorine, the unreacted excess has been classified as free available residual chlorine. As the pH of a solution containing 1.0 mg/l of free available residual chlorine is elevated, the oxidation potential decreases as shown in Figure 2. The curve plotted by Chang for 8.7 mg/l of free available residual chlorine is almost identical. The oxidation-reduction potential is a measure of the tendency chlorine has to react with other materials. Unfortunately, it is not a measure of the speed with which these reactions will take place. In essence, as the pH increases, chlorine tends to react with fewer substances, and it is generally accepted that, as the temperature increases, the reactions that do take place will be faster.

The oxidation reactions of chlorine with inorganic reducing agents are generally very rapid. Sulfides, sulfites, ferrous iron, and nitrites are examples of such agents. Some dissolved organic materials also react with chlorine rapidly, but the time required for completion of most organic chlorine reactions is a matter of hours.

The kinetics of the reactions of chlorine with ammonia, amino acids, and proteins, and the products produced by these reactions have been extensively studied. The common goal of this work was to theoretically explain the breakpoint process. Griffin has shown that when chlorine is added to water containing ammonia or ammonia ions, a residual oxidant is obtained. However, when the initial molar ratio of chlorine to ammonia is greater than 1, oxidation of ammonia and reduction of the chlorine starts to take place. When the initial molar ratio of chlorine to ammonia is around 2, all of the free ammonia is oxidized and chlorine reduced if sufficient time is allotted for the reaction. The reactions of chlorine with albuminoid nitrogen were found to produce a form of the breakpoint curve. But, the hump and the breakpoint in the curves were usually less discernible than those obtained with free ammonia.

The conclusion made from research has, essentially established that the reactions of chlorine with ammonia can be represented by equations 3, 4, and 5.



The rate of chlorine substitution and the reaction products are a function of the pH, temperature, time and initial chlorine to ammonia ratio. For pH values less than 5, the reactions between ammonia and chlorine may require several minutes. The actual products of the breakpoint reactions and the mechanics of the reactions are yet to be clearly defined. The amount of dichloramine (NHCl_2) formed during the reaction is also questionable. The amount of dischloramine formed is also a function of the temperature, pH, time, and initial ratio of chlorine to ammonia. Fair et al, report that the equilibrium condition between monochloramine and dichloramine can be expressed as follows:

$$\frac{(\text{NH}_4^+)}{(\text{H}^+)} \frac{(\text{NHCl}_2)}{(\text{NH}_2\text{Cl})^2} = 6.7 \times 10^5$$

This relationship for a chlorine to nitrogen molar ratio of 1 is plotted in Figure 3 (Curve A). Curves B and C in Figure 3 are the relationships obtained by Palin. In any event, at pH values below 6, some dichloramine formation is to be expected. Research also indicates that at pH values below 7.5 some nitrogen trichloride formation is to be expected as well.

The oxidation-reduction potential of the chloramines is much lower than that of free available chlorine and is also affected by pH. For pH values between 6 and 8, the chloramine oxidation potential is shown in Figure 2 with a similar curve for a 1.0 ppm combined residual formed with glycine. The influence of the ammonia-chlorine ratio upon the oxidation potential is shown graphically in Figure 4.

The lower oxidation potential of the ammonia chloramines indicate that they are less reactive than free available chlorine. The research on the reactions of free and combined available chlorine with various amino acids also indicates that the chloramines react slower and to a lesser degree.

Figure 5 presents an example of a break-point curve when a 0.5 ppm of dose of ammonia nitrogen is added to a chlorine demand free water. As the chlorine dosage is increased, the ammonia will be oxidized. The break-point, or near complete destruction of the ammonia will occur when the chlorine dosage is between 7.5 and 25 times that of the ammonia; either natural or added. The chlorine dose at the break-point, shown as B in Figure 5, is generally approximately 10 times the original ammonia concentration. The ideal type curve shown in Figure 5 is seldom realized because of the presence of complex organic compounds in the water.

BACTERIACIDAL EFFECTIVENESS

The primary purpose of the addition of chlorine to water is to destroy bacteria and other microorganisms. Trace amounts of free available chlorine prove to be very effective in this intended purpose. One belief is that the destructive action is a physio chemical one. Another theory postulates that because trace amounts of chlorine are effective, it implies that it must inhibit a key-enzymatic process.

Any change in the state of the chlorine which reduces its oxidation potential as for example, its reaction with ammonia or ammonia derivatives to form combined chlorine residual — reduces the rate at which it reacts with the bacterial cells and decreases its effectiveness as a disinfecting agent.

Available data show that, under most favourable conditions: (a) to obtain equivalent bactericidal action with the same period of exposure, about 25 times as much combined available residual chlorine as free available chlorine residual is required and, (b) to obtain equivalent

bactericidal action with the same amount of combined available chlorine residual as free available residual, a contact period of approximately 100 times as long is required.

Besides the type of residual having an effect on the chlorine residual required to effect disinfection, other factors such as pH, temperature, and type of water will also vary the requirements. See Figure 6 for a residual requirements curve secured in U.S. Public Health Service experiments at temperatures of from 20° to 25° C for 60 minutes with an exposure to combined available residual chlorine and also 10 minutes exposure to a free available residual chlorine. Figure 7 presents 100 per cent kill curves for chlorination as submitted by Butterfield.

CHLORINE RESIDUAL DETERMINATION

There are a number of methods available for determining chlorine residual in water. Four common methods are:

- Orthotolidine (OT)
- Starch iodide
- Palin (DPD method)
- Amperometric titration

The simplicity of the orthotolidine test (OT) has lead to its general use at water works plants. Even when a water treatment plant is equipped with newer amperometric titration facilities, check control is usually maintained with the OT method. A four point procedure for performing the OT test is:

1. Draw sample of chlorinated water. The tap should be kept running continuously or for a few minutes before taking the sample. When sample is collected adjacent to a hypochlorinator application point, a large volume sample should be collected over a number of injection cycles.

2. Allow sample to stand for 15 minutes to simulate the required minimum contact period.
3. Use 0.5 ml of orthotolidine (OT) reagent in 10 ml cells, 0.75 in 15 ml cells, and five ml in 100 ml tubes. Place reagent in testing tube; add sample to required volume; and mix. When the temperature of the sample is less than 68°F bring it to that temperature quickly after mixing with the OT.
4. A colour comparison is made when the maximum colour develops.

The above procedure is satisfactory for determining the total available chlorine residual. When the free residual is required the sample must be near 32°F when the OT is added and the colour comparison is made immediately. The orthotolidine-arsenite (O.T.A.) test can also be used to determine the free available chlorine residual.

The starch iodide method of residual determination may be used at sewage treatment plant and also for chlorine concentrations greater than that generally encountered in water works operation. The Palin method, although not generally used, can determine the free residual without refrigeration and cooling. Lack of sensitivity at lower residuals and reagent problems may be restricting factors.

The amperometric titration method of residual determination is to be preferred when complex chlorination programmes are adopted. With this method the free and total available residuals may be determined at any water temperature without refrigeration or warming procedures. With the need for continuous residual monitoring, to ensure the 100 per cent effectiveness of the chlorination process, the related chlorine residual recorder is becoming more important.

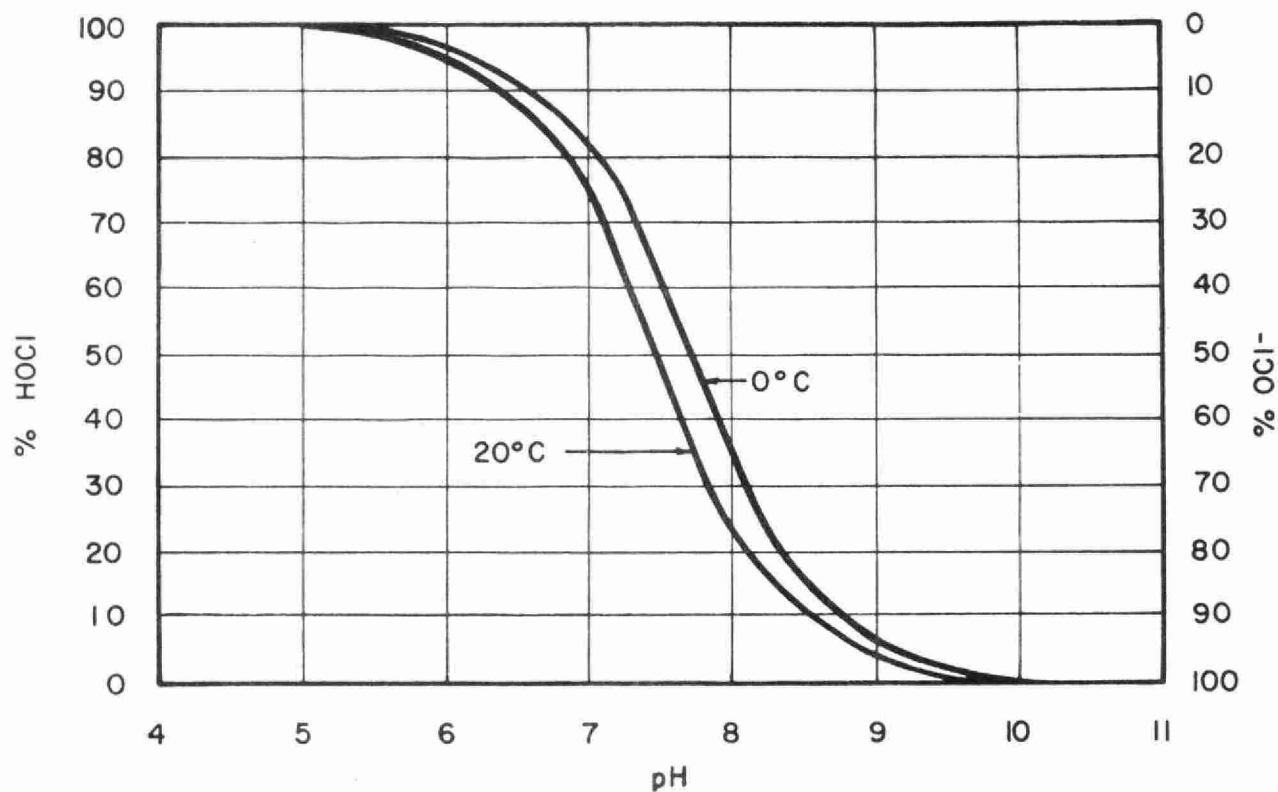


Figure 1

Relative amounts of HOCl and OCl⁻
present at various pH values

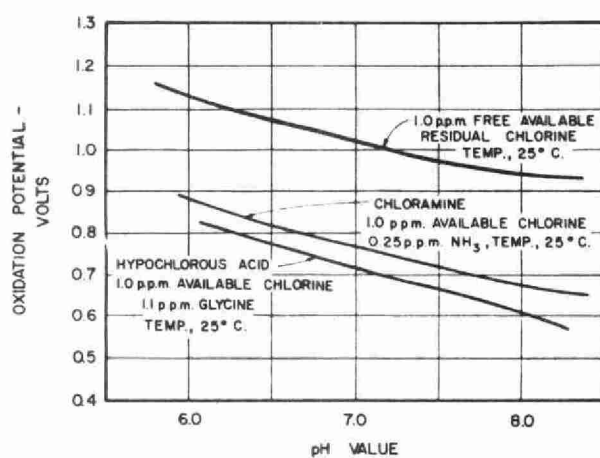


Figure 2

Variation of oxidation potential of solutions
containing different compounds of chlorine

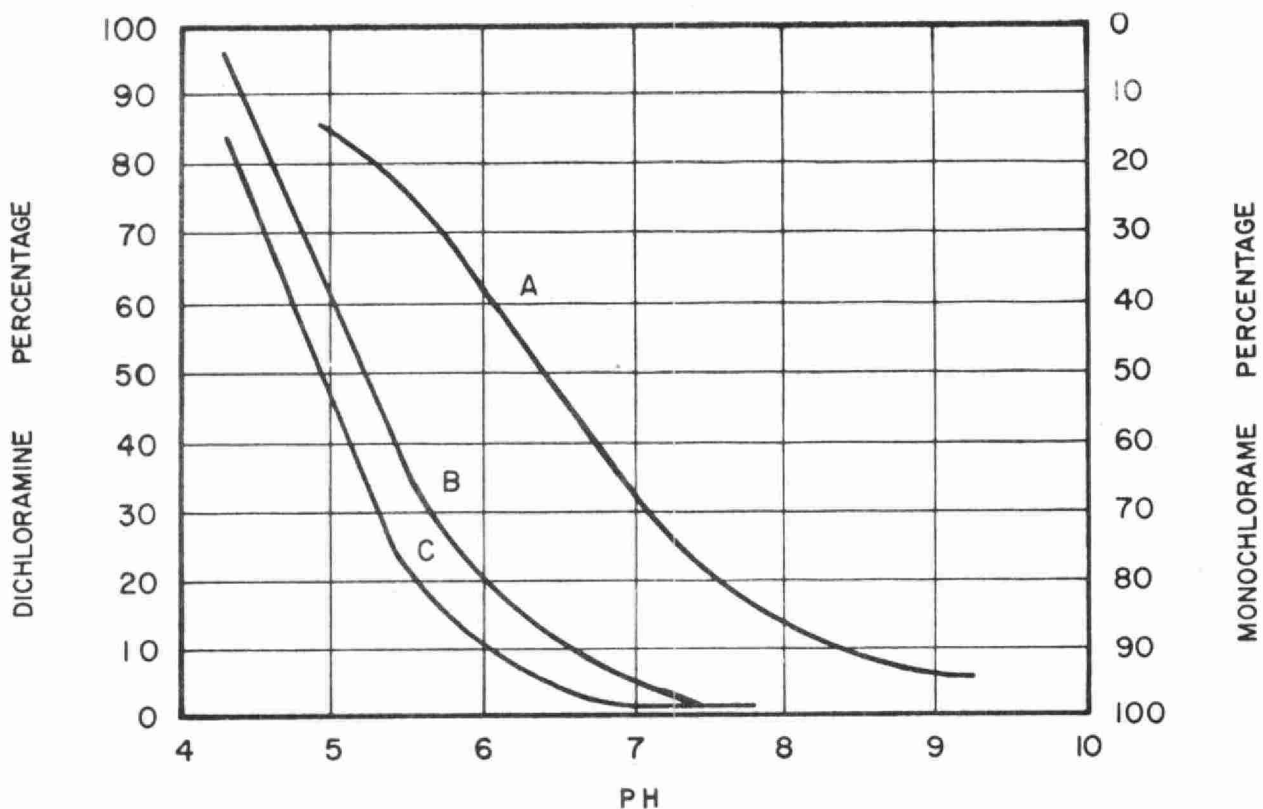


Figure 3

Relationship between NH_2Cl , NHCl_2 , and pH

- (a) Initial chlorine to ammonia weight ratio 5:1
- (b) Initial Cl_2/N weight ratio 2.6:1 contact period 10 mins.
- (c) Initial Cl_2/N weight ratio 5:1 contact period 10 mins.

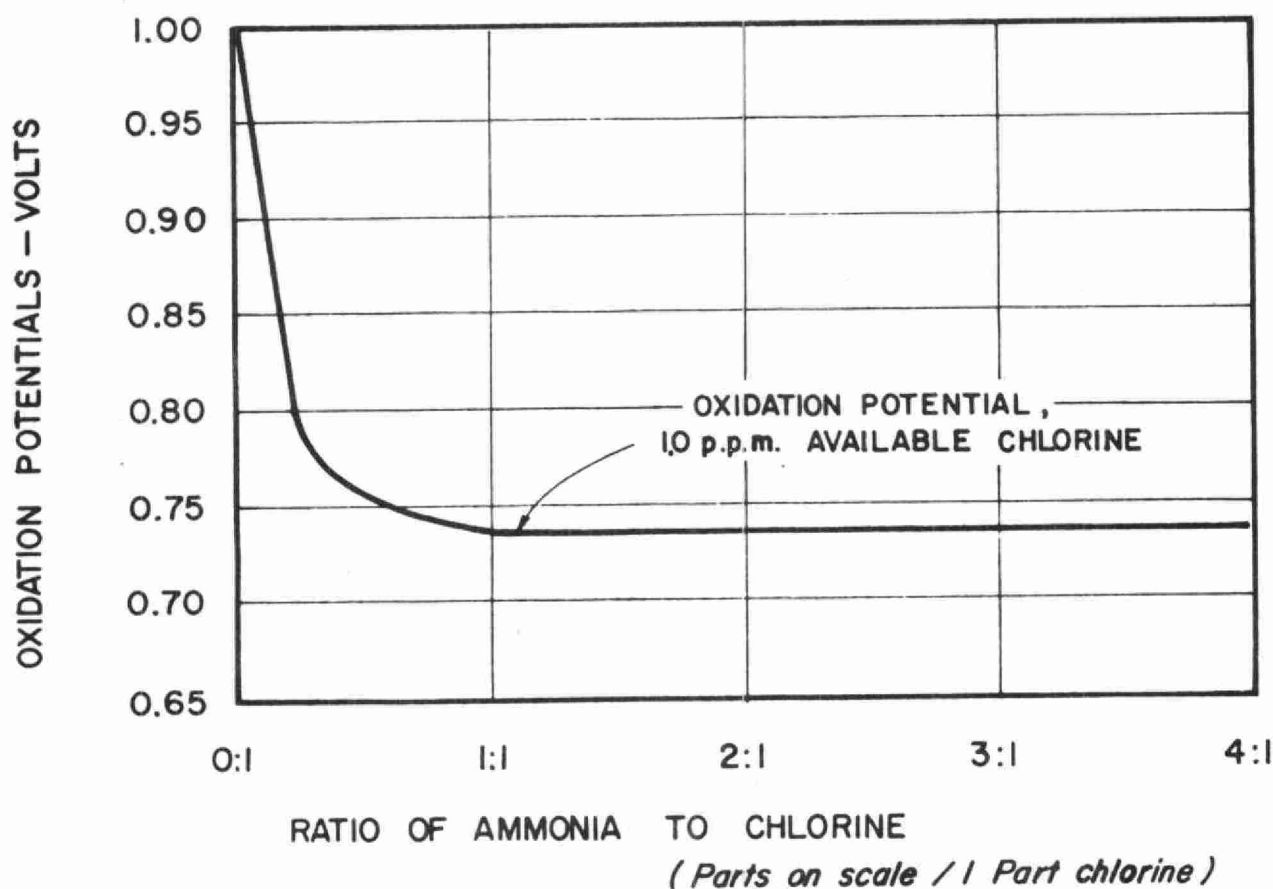


Figure 4

FIG. 5

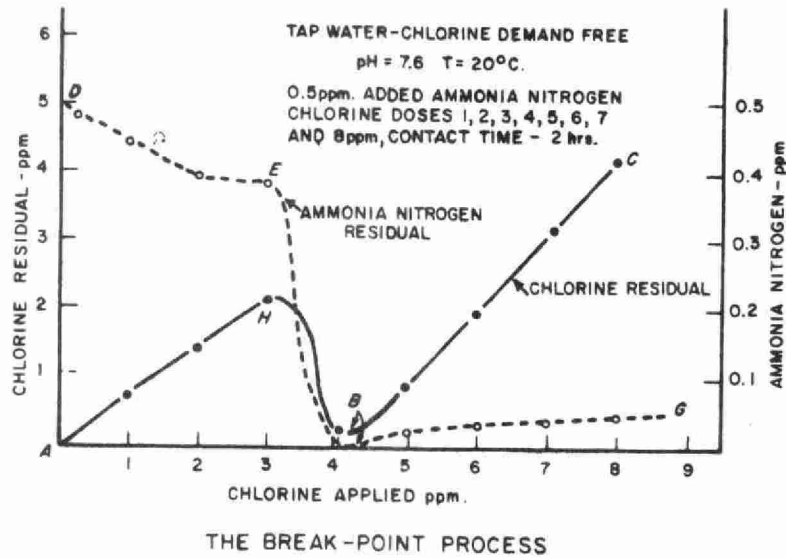
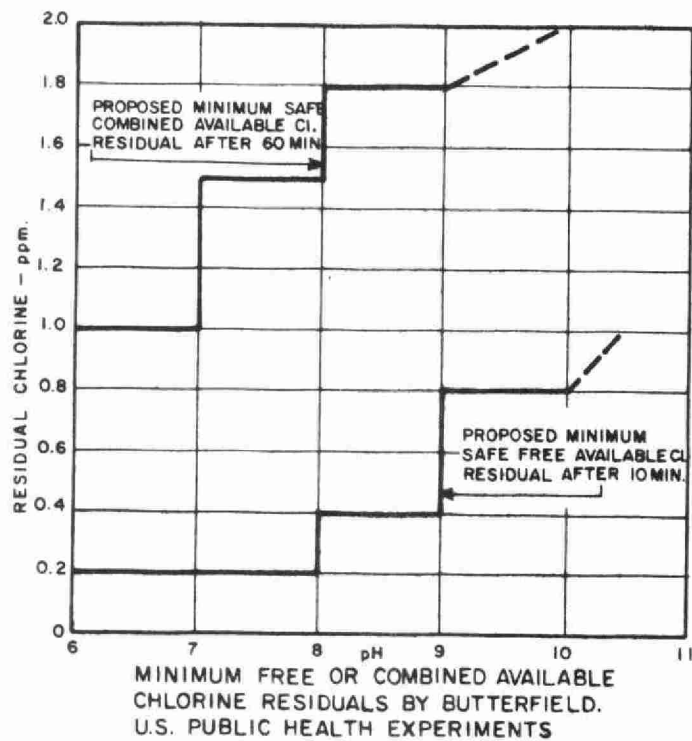
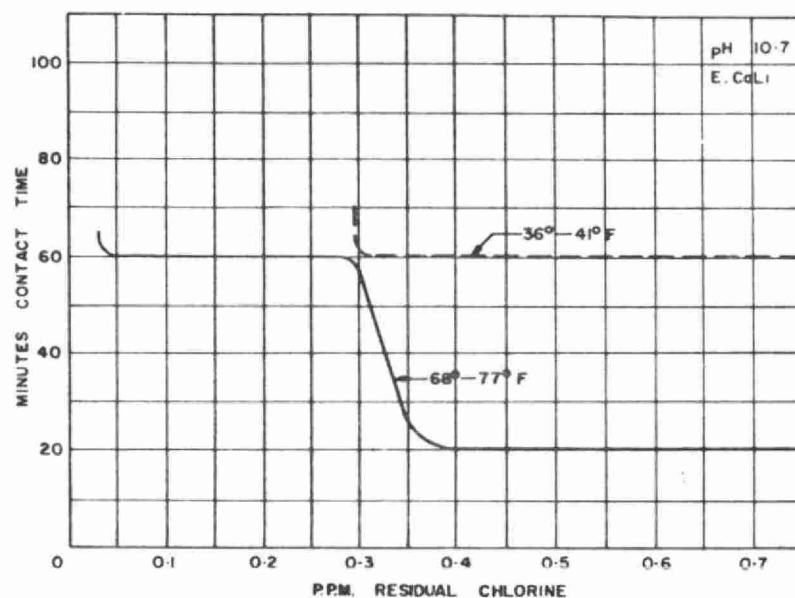
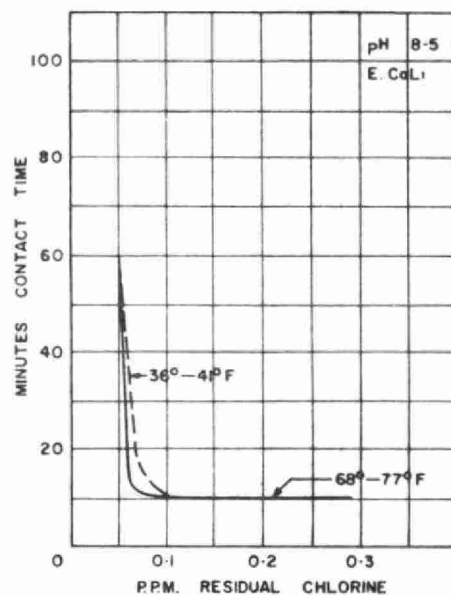
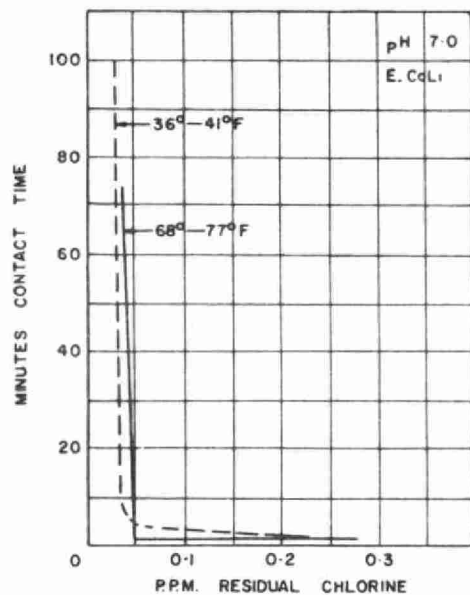


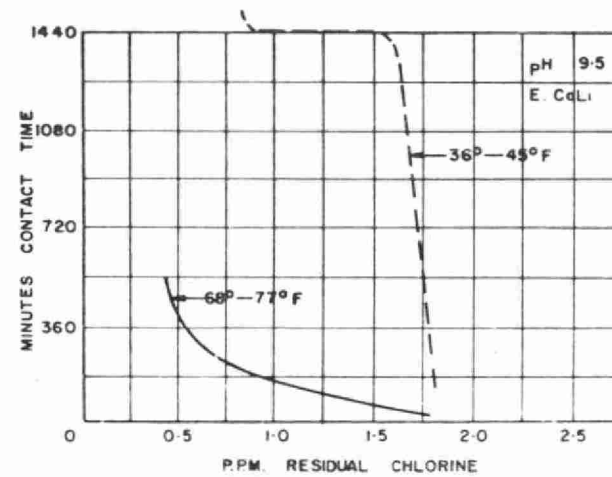
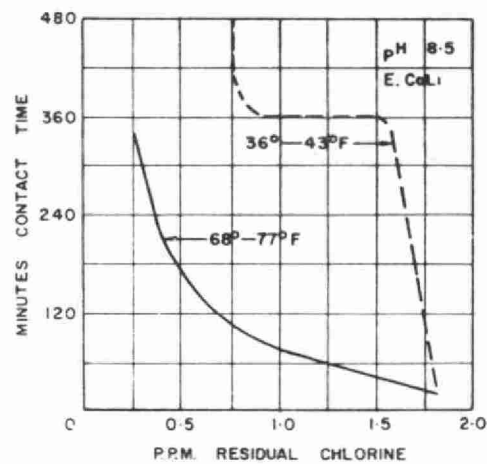
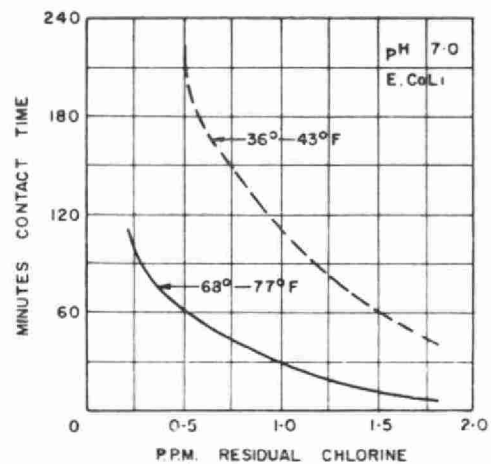
FIG. 6



100% KILL CURVES FOR CHLORINATION



100% KILL CURVES FOR FREE CHLORINATION



100% KILL CURVES FOR COMBINED CHLORINATION

DIVISION OF SANITARY ENGINEERING
ILLINOIS DEPARTMENT OF PUBLIC HEALTH T.R. 10-2
COMPILED MAY 1947

FIGURE 7

ALGAE AND OTHER INTERFERENCE ORGANISMS IN WATER SUPPLIES

M. F. P. Michalski, Biologist

Division of Laboratories

WHAT ARE ALGAE?

Algae are plants just as trees and grass are plants. They are green, they manufacture their food in the form of starches or oils by using the energy of sunlight and the nutrients they extract from the water. In the classification of plants, they are considered to be the most primitive groups, and some of the algal forms commonly found in water supplies are thought to be similar to the first life on earth. They are considered primitive because each cell is capable of carrying out the complete life history as no specialization has been developed into various tissues such as are found in the higher plants (stems, roots, leaves, seeds). All higher plants and animals are composed of millions of cells. Throughout the ages, certain cells of plants and animals have arranged themselves into specific organs (kidney, heart, liver, skin) which carry out a highly specialized function. In algae, each individual cell fulfills all such functions, i.e. excretion, respiration and reproduction.

VALUE OF ALGAE

The waterworks operator often looks upon algae as purely a nuisance as it clogs filters, imparts tastes and odours to the water supply, and causes growths on reservoir walls. However, a number of beneficial aspects of algae can be cited.

Algae are the basis of all life in water. On land, grass feeds the rabbit which in turn is eaten by the fox and while the fox does not eat grass, there would be no foxes if there were no grass. This is called the food chain and the basis of the food chain in water, is algae. Algae feed minute animals which in turn provide the food for pickerel. Thus, if there were no algae, there would be no pickerel. It can be demonstrated that fish production in a lake varies directly with the amount of algae that the lake produces.

Algae provide food for man. Algal forms contain protein, carbohydrates, fats, vitamins and inorganic substances. Some 25 - 30 different species of algae are eaten by the Japanese. Similarly, food for waterfowl is provided by algae.

Man is currently controlling planktonic types to accomplish work. Algae, through their photosynthetic activities are able to convert inorganic compounds into organic compounds and oxygen. The generation of this oxygen may be utilized in the stabilization of waste waters in oxidation ponds. The provision of oxygen by aquatic plants and algae plays an essential role in the purification of streams, rivers and lakes. An oxygen balance is essential for fish life and helps in maintaining a suitable environment for the productivity of fish food organisms.

Some algal forms may be used as indicators of pollution as certain species are either extremely sensitive or resistant to various types of pollutants.

Certain algae and aquatic plants keep the water temperature low by their shading effect. The green alga *Chara* is responsible for keeping water temperature low enough to allow trout to be supported in many farm ponds in southern Ontario.

Because of the relatively simple structure and nutritive requirements, many of the algal forms are ideally suited for research projects. When the first men start making long-distance trips into space, the food they probably will consume will be algae grown in the space capsule.

A few blue-green algae (*Anabaena*, *Gloeocapsa* and *Nostoc*) are able to fix atmospheric nitrogen. This process is essential in the growing of certain crops such as rice.

SIZE AND DISTRIBUTION

There are several thousand different species of algae that live in the waters of Ontario. These range in sizes from a plant as much as four feet tall down to cells which are so small that they can barely be seen when magnified a thousand times by a microscope. Algae live in oceans, lakes and rivers, down to a depth where the light can penetrate, and in some instances even below the euphotic zone (illuminated upper water layer). Also, they live on the damp soil on the face of glaciers, and in combination with fungi to produce the lichens we are all familiar with.

GROWTH REQUIREMENTS

Algae are very specific in their needs. The types that are characteristic of lakes are seldom found in streams and those which populate a lake in summer give way to other forms in winter. Some species can only live in very pure water and others are obligated to polluted situations and even sometimes to a particular type of pollution.

Factors governing the type and number of algae are environmental (i.e. temperature, available light, diffusion currents etc.) and nutritional (i.e. phosphorus, nitrogen, manganese, iron, pH, etc.). No two species of algae have exactly the same requirements.

SIGNIFICANCE AND INTERPRETATION OF ALGAE

Algae are normal and constant inhabitants of nearly all natural surface waters. Wherever algae grow, there too will be found bacteria, fungi, and various animals. These different organisms interact in the open waters to carry on a chain of life. The algae as green plants use the dissolved solids (nutrient minerals), water and carbon dioxide to grow and reproduce. Bacteria and animals feed on the dead or live organic algae. The bacteria in turn die, and their bodies are broken down, thus eventually returning the elements to the mineral conditions. If any part of this cycle were to be eliminated or altered, the resulting water might contain materials that would cause tastes and odours, or be otherwise undesirable as a water supply.

The more frequently observations on a raw water source are made, the greater the likelihood of noting the beginning of increased algal populations. Counts may vary a few hundred areal standard units per millilitre for an extended period, then increase perceptibly to a few thousand areal standard units per millilitre within three to four days. (One areal standard unit is the equivalent value of an areal value of 400 square microns). Such increases may result from growth stimulated by a change in the weather; by an increase of nutrients from sewage effluents, land drainage, precipitation, or applied fertilizers; or from planktonic masses drifting out from adjacent fertile tributaries.

Excessive numbers of one algal type may cause no end of trouble in the water treatment plants. It is therefore important for the plant operator to know what is in the water. No specific rules can be set down which will account for all local circumstances and it would be misleading to quote a number of plankton counts and imply that the consequences of each would always be the same.

Water works operators can learn a great deal about the general quality of the water by an examination of the phytoplankton populations. Certain generalizations can be made:

- (a) Severely polluted, warm or hard waters tend to encourage blue-green algal forms.
- (b) Cold, clear waters generally favour diatoms.
- (c) Green algae tend to be abundant during spring and late fall seasons.

Thus, one of the great benefits that can result from a systematic programme of phytoplankton counting is to predict expected "blooms".

ALGAE PROBLEMS IN THE WATER SUPPLY SYSTEM

The operator can be faced with problems created by algae of several kinds. In all cases, they result from an overabundance, but the numbers required to create this difficulty will vary.

Filter Clogging

The reduction of filter runs, caused by the coating on the surface of the filters with large numbers of these minute plants is probably the most common and serious problem that algae create for waterworks operators. Certain waters at certain times of the year produce a great abundance of the filter clogging species and under the worst conditions may reduce the production of water through a filter to a point where there is hardly sufficient water to back-wash. The most common trouble makers in this regard are the diatoms Asterionella, Melosira, Synedra, Tabellaria, Fragilaria and Stephanodiscus. The rigid cell walls of these algae are highly silicified and not subject to decomposition. Therefore, even though the diatoms may die off rapidly on the surface of the filter, their silica walls remain to plug the pores in the sand. It is difficult to make definite statements concerning the relationships between algal populations and filter clogging owing to varying biological, chemical and physical conditions and the efficiency of pre-filtration processes. Generally speaking, when diatom levels from 2,000 - 2,500 a.s.u. per ml. are present, difficulties in maintaining normal filter runs may be anticipated. Also, certain of the summer blue-green algal forms such as Oscillatoria and Aphanizomenon may develop in sufficient numbers to reduce filter runs. A dramatic example of reduction in filter runs occurred in November of 1962 when the diatom Melosira temporarily affected nearly all water works between Hamilton and Kingston and the plant at Scarborough was removed from service entirely for several days.

Taste and Odour Production

Algae are capable of producing tastes and odours that will persist through treatment and cause consumer complaints. Tastes and odours may be caused by a variety of ways. First, bacteriological doses of chlorine often rupture cell walls, thus expelling the cell contents into the water. Second, certain blue-green algae such as Anabaena, Aphanizomenon and Microcystis are well known for developing very foul "pig-pen" odours in water. These blue-green forms collect in large masses sufficient to form water-"blooms". The foul odour probably develops from products of decomposition as the algae begin to die off in large numbers. Third, some algal forms are capable of imparting metabolites to the water. These compounds, either alone or in combination with other organic compounds, have the ability to produce tastes and odours.

In recent years, a number of small northern Ontario lakes (Apsey Lake, near Espanola, Clarke Lake near Bancroft, Turner Lake near Cache Bay and Gull Lake near Kirkland Lake) have supported one or more species of odour-producing flagellated algae including

Synura, Trachelomonas, Peridinium, Dinobryon and Ceratium. These lakes do not appear to be enriched either on the basis of their chemical and physical attributes or their level of primary productivity. Nonetheless, these lakes have been rendered periodically unpalatable because of the presence of small numbers of one or more flagellated species.

Often tastes and odours are the result of decomposition products of rooted aquatic vegetation. Raw water supplies that come from shallow, weedy lakes almost invariably have a continuous or intermittent problem with tastes and odours. This problem is usually most acute late in the fall when the ice-cover has just formed and again in the spring at the time of break-up of ice-cover.

The nature of odours vary with the types and levels of algae present in the water. The various odours have been described as weedy, fishy, cucumber, grassy, etc. The diatoms Fragilaria, Asterionella, Synedra, Melosira, Tabellaria and Stephanodiscus have been known to affect the palatability of the water when levels exceed 2,000 a.s.u. per ml. In contrast, C. M. Palmer in a recent publication reported that a cucumber-like odour was produced at Charlottesville, Virginia with only 48 a.s.u. per ml. of Synura.

Growths in Reservoirs

A third common problem that algae create in a water works operation is growths in reservoirs. Here the algae may grow attached to the walls where they form a heavy mass of material. This algal mass may be alive with crustaceans and insect larvae. Occasionally, one of these little animals may come through the taps and shake the confidence of the consumer in the purity of the supply. Algal growths in the reservoir may be of a free-floating type. These growths may impart tastes to the water. Probably the most common algae causing difficulty in reservoirs is one of the larger species called Chara. This algae grows to a height of two or three feet in a soft mud bottom and is typical of the cold, hard water commonly found in spring water sources. Where such water is collected and stored in an open reservoir this algae invariably grows and is difficult to control.

CONTROLLING ALGAE

There are two basic means of controlling algae and solving the problems that they create; one, by controlling the environment in such a way as to make it an unsuitable place for them to live, and two, by treatment practices. The latter method is less satisfactory in the long run as it necessitates adding chemicals that are costly on either a continuous or intermittent basis. Controlling the environment is a more satisfactory means, though this is not always possible.

Environmental Control

The best method of this type of control is by selecting the best possible source of supply. A deep, cold lake rather than a shallow, warm productive lake should be chosen. In choosing a new supply care should be taken to utilize water of low fertility as judged by chemical analyses and the algae population that it maintains. Routine biological and chemical samples should be obtained for at least one year previous to the installation of any water works facilities. Limnologists would then be able to determine the numbers and kinds of algae present and assess the suitability of the water. Where the municipality controls the land adjacent to the supply, care should be taken to keep out surface drainage and other possible nutrient sources. Run-off from buildings, domestic sewage and certain industrial wastes are rich in plant nutrients and should be avoided as only small amounts of these fertilizing substances can induce the development of high algae populations.

Another aspect of environmental control is to exclude the light by covering pre- and post-treatment reservoirs. The easiest method is simply to cover the reservoir, although this is often not done and algae problems continue year after year. This may be achieved by a permanent cover such as concrete or a black plastic sheet spread over the reservoir. While the latter method has not been used, it would be effective in excluding light and be relatively inexpensive to apply. A second method of reducing light in pre-treatment reservoirs is to use activated carbon to induce an artificial turbidity. While this is only a temporary measure and must be repeated every four days, it has the added advantage of absorbing taste and odours from water while in suspension and keeping the bottom accumulation sweet. Carbon can only be used in the raw water where the treatment includes complete filtration.

Treatment Practices

(a) Control of Filter Clogging Algae

The obvious way to solve the problem of short filter runs is to remove the algae before they get to the filter. The common method of removing algae from raw water is the use of settling basins which may follow flocculation and pre-chlorination. Micro-strainers are also being used to remove the algae before the water is filtered. A third method is to apply algicides to the raw water and thus remove them before the water enters the plant.

The principle of removing algae by flocculation and sedimentation involves trapping the algal cell in the alum floc and carrying it to the bottom with other unwanted solids. When algae populations are very high they often hold the floc in suspension long enough for it to pass through the settling basins and onto the filters. This floc and the algae can be settled if weight can be added to the floc. A slurry of ordinary clay mixed and fed during the periods of difficult times will do much to get the operator over a short-term period of difficulty. By increasing the

dosages of alum and heavier pre-chlorination you may assist in alleviating short filter runs.

(b) Chemical control

While there are many algicides sold today, only two are suitable for use in a domestic water supply namely copper sulphate and chlorine. The cheapness and availability of copper sulphate and its safety from a public health standpoint make it the most satisfactory chemical to use. The effectiveness of copper sulphate varies somewhat with the chemical composition of the water. In hard water the copper precipitates rapidly thus, more is required than in soft water. As a rule of thumb .25 ppm will kill most algal forms although a dosage of .5 ppm is required for some forms. Copper sulphate is very toxic to fish and about 1 ppm is about all they will stand. Copper sulphate is sold in a variety of crystal sizes. The method of application varies with the grade of crystal used. In general, the finest crystals may be distributed on the surface of the water as they will immediately dissolve. Larger sized crystals may be dissolved in water and pumped as a spray or they may be put in a burlap bag and towed through the water in such a way as to provide an even distribution of the calculated amount of the chemical over the entire surface of the reservoir. The operator must know the depth of water as he applies the chemical and sees that the deeper water gets proportionally more chemical than the shallow areas.

In applying chlorine, a rough calculation must be made of the volume of water being treated and the pounds of chlorine required to satisfy the demand and still provide a residual of 1 ppm. The calculation is used as an initial guide, then followed by chlorine tests to provide the final adjustments. A similar calculation must be made for determining the amount of copper sulphate but more care must be exercised as no simple test can be used as a guide. To do this, the surface area of the water to be treated must be obtained together with the average depth of the water. When multiplied these two figures give the volume of water in cubic feet. The total number of pounds of water may then be calculated by multiplying the volume by 62.5. As one part per million (ppm) equals 1 pound per million pounds of water, the treatment of a reservoir with .5 ppm would require one half pound for each million pounds of water.

Area x average depth x 62.5 = lbs. of water in reservoir

1 ppm = 1 lb. per million lbs. of water

The ideal time to apply chemicals is when the algae population is rising but before the condition becomes acute. If treatment is postponed until a very dense growth of algae occurs the sudden killing of this material and the subsequent decomposition may remove all the oxygen from the water causing it to go septic, kill the fish, and become foul-tasting. If the condition gets out of hand before treatment can be applied, half the reservoir should be treated first to reduce the population; after a week or so has

been allowed for this material to decompose, the total reservoir area can then be treated.

(c) Microstraining

Microstraining as a method of water treatment was introduced in Ontario about 9 or 10 years ago. There are about 6 installations operating on municipal water supplies. The development of this means of filtration was made possible by the invention of an extremely fine wire mesh capable of removing such small particles as algae from the water and yet capable of passing high volumes of water. The principle of the microstrainer is simply a rotary screen where the raw water is fed to the inside and flows out through the screen material. The drum is about three quarters immersed and as it turns around, a jet of water is played on the surface of the screen and knocks down the accumulated solids and algae into a hopper and from there are carried to waste.

In water treatment the microstrainer has two uses:

- (a) as pre-treatment for algae removal ahead of conventional sand filters,
- (b) as sole treatment for waters for the removal of algae and other extraneous material where turbidity is not a problem.

Microstrainers have proven very effective in extending the operating time of conventional sand filters during times of heavy algae "blooms". In one instance, runs of not less than 20 hours have been obtained where previously 6-hour runs in summer were not uncommon and as little as two hours were experienced. Where a microstrainer is used as a sole means of water treatment it should never be installed with the thought of reducing turbidity. Where it has been used solely for the removal of algae and the protection against the variety of water fleas, insect larvae, leeches and aquatic worms, that commonly pass through unprotected water supplies, it has been found to be very satisfactory.

(d) Control of Algae-Caused Tastes and Odours

Two methods are commonly used in controlling tastes and odours; one, the feeding of activated carbon and two, variations in the method of chlorination. Activated carbon is the only sure method of taste removal, but this on a continuous basis is somewhat expensive. Also, this method is somewhat messy. Another method of controlling tastes and odours is to alter the method of chlorination. Super-chlorination or break-point chlorination may be helpful. These methods must be tested as the algae may be killed leaving the decomposition products to make conditions worse. The use of chlorine dioxide or chloramine at various points of application in the plant may assist in controlling tastes and odours but this is an individual problem within each water works and can only be determined through experimentation.

WATER MAIN INFESTATIONS

While water main infestations do not necessarily come under the title of this section, there has been considerable interest in this matter in recent years, and so perhaps a little of the fact and fiction should be separated. It is probable that most if not all water distribution systems contain living organisms of some kind. A brief survey of the literature indicates the wide variety of animals that have caused difficulty from time to time. These have included nematodes, aquatic earth worms, snails, clams, a variety of aquatic insect larvae, leeches, Gordian or horse hair worms, Daphnia or water fleas, etc. Many of these have occurred in municipal supplies having complete treatment of flocculation and sand filtration. The method of entering the distribution system often remains a mystery though in many cases it is thought that the minute egg passes through the sand bed and develops subsequently in the distribution system. This problem is not more widespread because the inside of a water main is relatively clean so that food is available only in very limited quantities. In some cases the life cycle cannot be completed entirely under water so that insects such as blood worms cannot reproduce in the water main.

Nematodes or roundworms

These are very small animals barely visible to the human eye. Some authorities consider them to be the most numerous animals on the earth as they are found in the soil, on lake bottoms, along the shores, in sewage sludge and in fact in almost any sample of earth. In view of their great numbers, it is not surprising that a few of them find their way into water distribution systems. Here they are able to subsist on the thin coating of slimes lining the water main and in organic depositions in low flow sections of the distribution system.

In this country, Nematodes have no public health significance; they carry no diseases, and are not human parasites. Although it is not likely known, many Nematodes are consumed by an individual every year in raw fruits, salads, vinegar and perhaps even in his drinking water. They are quite resistant to chlorination and the levels normally applied for the control of pathogenic bacteria are not sufficient to kill Nematodes. In this respect, we are fortunate as this climate controls some species that are a serious human problem in the Middle East and Asia.

Control of Infestation

As most of the organisms that inhabit water mains are resistant to normal water works sterilization procedures and as no chemicals are suitable for adding to water to control this type of nuisance organism, good housekeeping is the only effective

control. As much as possible of the organic material should be kept from the water mains. This is best accomplished through chemical precipitation and sand filtration. In laying water mains, low flow areas should be eliminated as much as possible, as they provide a refuge. Where dead ends occur in the system, they should be flushed routinely. In this way, it will be possible to maintain the confidence of the consumer in the products that you deliver.

CONCLUSION

This lecture has only touched very lightly on the high spots of this subject. Future courses will provide further and more detailed information. In the meantime, for those interested in learning more of this subject, a book recently published by the United States Public Health Service is well worth your reading and cannot be too highly recommended. The title is *Algae in Water Supplies*, by Mervin C. Palmer. It is available from the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C. for the price of \$1.00.

As the operator can hardly be expected to be a competent Biologist, Chemist, mechanic and gardener, problems in the identification of unknown organisms arise from time to time. It is the intention of this laboratory and certainly the Biology Branch to assist wherever possible. In this regard, consultative and identification services are available and provided to the limit of the capabilities of our small staff. If specimens such as insects, algae, etc., are to be sent for identification, it is important that they be preserved. Formaldehyde is cheap and effective and can be purchased from any drug store. If the sample is put in a solution of about 5% formaldehyde and 95% water, it will be assured of arriving in good condition.

DISINFECTION OF WATER SYSTEMS AND APPURTENANCES

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GENERAL

The installation of new water mains and equipment or the repair of broken mains and appurtenances may lead to contamination of a water supply if an adequate disinfection programme is not undertaken. Such a programme must include precautionary construction practices, suitable flushing and chlorination of the affected portion of the system, and bacteriological testing to determine the adequacy of the disinfection programme.

Not only is disinfection employed to protect the health of the consumer but it is also required to prevent the growth in the system of various water-borne nuisance organisms. Thus, although disinfection is carried out primarily for the destruction of disease-causing bacteria, it is also used for the elimination of non-pathogenic micro-organisms which can cause colour, taste and odour problems.

DISINFECTION OF NEW MAINS AND APPURTENANCES

1.1 Preliminary Precautions

The effectiveness of disinfection depends to a large extent upon keeping pipes and appurtenances free of dirt and foreign material during construction. Caked-on material will generally not be removed during flushing operations. Subsequent chlorination then becomes ineffective since chlorine is considered to be a surface contact disinfectant.

Since pipes awaiting installation at the job-site may accumulate debris and dirt these should be visually inspected.

and, if necessary, cleaned prior to lowering into the trench. In some cases the inside of the pipe may have to be swabbed with a strong chlorine solution applied to a mop-head pulled with a cord through the pipe. It may become necessary in some instances to cover both ends of a pipe before lowering it into a trench to ensure that it does not pick up earth from the trench walls. The ends of the pipe should be checked and cleaned before final coupling. If ground water is a problem in the trench, a water tight plug should be inserted in the pipe end immediately. Ground water will carry mud and it may be contaminated by sewage from severed laterals. A plug should also be used in the last laid section of pipe during any unattended period to prevent entry of small animals or foreign material such as gravel, metal fittings, sticks, or packing.

Appurtenances such as valves, meters and corporation cocks should be kept packaged and clean until ready for use. These may be disinfected immediately prior to installation by thoroughly cleaning all surfaces and brushing on a one percent chlorine solution. Meter parts should not be overly exposed to strong chlorine solutions.

1.2 Flushing

Flushing of a water main should be carried out only after the pressure tests have been made and the pipeline found acceptable. The pipeline should be thoroughly flushed through hydrants or specially installed taps to develop velocities of at least 2.5 feet per second. Hydrants or flush out valves must be installed at the ends of mains to facilitate flushing of dead-end sections. The following table indicates the size of opening required and the flow involved at 40 psi pressure to ensure the provision of the minimum flushing velocity.

Table No. 1
Required Opening Size for Minimum 2.5 fps Flushing Velocity

Pipe Diameter (inches)	Flow (gpm)	Opening Size (inches)
4	100	15/16
6	220	1 - 3/18
8	390	1 - 7/18
10	610	2 - 5/16
12	880	2 - 13/16
14	1200	3 - 1/4
16	1565	3 - 5/8

It can be seen from Table No. 1 that adequate flushing velocities may not be attainable in mains over 16 inches in diameter. For this reason extra precautions should be taken to ensure that large pipes are absolutely free of dirt and debris during construction.

The procedure for flushing requires that hydrants and special taps be opened in order starting from the feed source and gradually working out towards dead-ends. The interconnecting gate valve controlling flow from the system should be released only after the first hydrant valve has been opened. Flushing must be a continuous operation until completed when the final hydrant and interconnecting gate valves are closed simultaneously. This procedure avoids the possibility of unchlorinated water flowing back into the feed main and carrying contamination into the potable water supply.

1.3 Chlorination

There are several sources of chlorine available and various methods of application for the disinfection of water-mains. While gas chlorination is the most economical its application is generally limited to new water works systems. The development of direct-mounted chlorinators, however, could increase the use of gas systems for watermain disinfection in the future. Other types of chlorine include 70 per cent H.T.H. (calcium hypochlorite) powder or tablets, and liquid sodium hypochlorite at 15, 12, and 6 per cents

available chlorine. There are advantages and disadvantages to the use of each.

Powder and tablets are the simplest to use, being deposited in each pipe length. However their use has the disadvantage that the system cannot be thoroughly flushed prior to chlorination, and there is a lack of control on concentration and mixing of the chemical. Many tablet adhesives have been found inadequate to hold the tablets in place during flushing. As a result they are often flushed out or carried to the ends of the lines before dissolving. A further disadvantage is that when water temperatures are below 41°F. the slow dissolving rate of the tablets precludes their use.

Powder may of course be dissolved in solution and injected as a liquid hypochlorite solution manually or through the use of a small positive displacement pump. The latter is more desirable as it provides steady dosing of the water entering the new mains. The preferred point of chlorine application is near the beginning of the main extension through a corporation cock installed in the top of the main. The chlorine dispensing apparatus should be located close to and on the downstream side of the interconnecting gate valve controlling flow into the new mains. The procedure for manipulating valves is similar to that used for flushing. This prevents a back-flow of highly chlorinated water from entering the potable water supply.

The highly chlorinated water must be retained in the mains for a period of at least 24 hours and produce a minimum 10 ppm available chlorine residual at the end of that time. This will generally require a starting residual of at least 50 ppm. This matter is currently under review by a committee of the AWWA which is considering an increased dosage to produce a 25 ppm available chlorine residual after 24 hours. Apparently the relatively small increase in cost for additional chlorine, in some cases, more than offsets cost by delays which result when flushing and chlorination procedures must be repeated because of unsatisfactory disinfection.

The amounts of gaseous, powdered or liquid chlorine required to produce a 50 ppm chlorine dosage may be

calculated for any section of watermain. The following sample calculations are for one mile of 8 inch watermain which will hold 11,500 Imp. gallons (I.G.) of water.

Table No. 2

Chloride Requirement Sample Calculations

- | | |
|----|--|
| A. | <u>Chlorine Gas Required</u> (consider 100% effective) |
| | $50 \text{ ppm} \times 11,500 \text{ I.G.} \times \frac{10 \text{ lb.}}{\text{I.G.}} \times \frac{1}{10^6} = 5.75 \text{ lb. gaseous chlorine}$ |
| B. | <u>70% HTH Required</u> (consider 75% effective) |
| | $= \frac{5.75 \text{ lb. chlorine}}{0.70 \times 0.75} = 11.0 \text{ lb. of 70% HTH}$ |
| C. | <u>15% Sodium Hypochlorite Required</u> (consider 75% effective) |
| | $= \frac{5.75 \text{ lb. chlorine}}{0.15 \times 0.75} \times \frac{1}{10} = 5.12 \text{ I.G. of 15% Solution}$
<div style="text-align: center;">$\frac{\text{lb.}}{\text{I.G.}}$</div> |

Similar calculations can be carried out for 12 and 6 per cent sodium hypochlorite solutions both of which should be calculated considering only 75 per cent effective available chlorine. The chlorine residual should be checked at each hydrant or special flushing tap and the 50 ppm residual assured prior to closing the valve at that point. For this purpose litmus paper or orthotolidine testing solution may be used. The orthotolidine test will produce a solution with a deep yellow-orange colour. The exact chlorine residual may be determined by diluting the solution with chlorine-free water to a level where a colour comparator can be used. After 24 hours the chlorine residuals should again be determined.

1.4 Bacteriological Testing

Following the required retention period the highly chlorinated water shall be completely flushed from the

treated main at its extremities until the replacement water throughout its length has a chlorine residual comparable to the potable water in the supply system. Only then should bacteriological samples be obtained from various outlets along the new main. Should these samples prove to be bacteriologically satisfactory, then the new main may be placed into service. However, in the event that these results are adverse, then the disinfection programme must be repeated until satisfactory results are obtained.

DISINFECTION OF OTHER EQUIPMENT

2.1 Reservoirs and Storage Tanks

As with watermains, reservoirs and storage tanks must be thoroughly cleaned before disinfection is attempted. All dirt, scale, loose paint, and other material must be removed. This may require cleaning down the walls and floor using a steel brush.

Disinfection can be accomplished by spraying a strong 250 ppm chlorine solution on cleaned surfaces from a portable back-pack or other mechanical spray unit. Caution must be exercised in using this method as chlorine fumes are toxic. The reservoir or storage tank should be adequately ventilated before entering, with the worker wearing protective clothing and goggles and utilizing an air mask with a bottled or outside source of air supply. A second worker, with protective mask readily available, should be stationed outside the tank or reservoir within sight of the inside worker in case of emergency.

A second method of disinfection which is satisfactory for small tanks requires the filling of the tank with a 50 ppm chlorine solution. All air must be removed from pressure tanks while filling with chlorine solution to ensure contact of the chlorine with all inside surfaces. As with watermain disinfection, a minimum 10 ppm chlorine residual should be present after a 24 hour retention time. In an unpressurized tank the wall surfaces and ceiling, above the water line, should be flushed with a strong chlorine solution.

Bacteriological samples should be taken only after the disinfecting solution has been fully removed and the chlorine residual in the tank the same as that in the supply system. If bacteriological results are satisfactory then the facility may be placed in operation; if not then the disinfecting procedures must be repeated.

2.2 Wells and Equipment

Since most well water is not chlorinated on a routine basis, primary disinfection is very important. All equipment contacting potable water, such as pumps, casings, drop pipes and other well appurtenances, must be thoroughly disinfected prior to being placed in service.

Before installing drop pipe and pump remove all surface mud and debris. When the pump is installed apply a chlorine solution to obtain a 50 ppm chlorine residual in the well. Then operate the pump in order to obtain a strong residual at the end of the newly constructed distribution feed line. Where a long feed line is involved, the chlorine should be added slowly and continuously to the well. The highly chlorinated water should be retained in the well and distribution feed line for a 24 hour period. Where possible some of the heavily chlorinated water should be returned back down the well between the casing and the drop pipe during the first 30 minutes of pumping in order to wash down and disinfect the inside of the casing.

After all disinfection water has been removed from the well and distribution feed line, samples should be obtained for bacteriological analyses. Adverse bacteriological results should be followed by a repeat of the disinfection procedures. Continued adverse results may be attributed to ground water contamination in which case continuous chlorination of the supply will be required.

DISINFECTION OF REPAIRED MAINS AND APPURTENANCES

3.1 Major Repairs and Planned Connections

Leaks and breaks in existing mains may occur at any location in a system. Major repairs and the planned installation of valves and other appurtenances in an old system will require partial or total dewatering of the affected section of watermain. The locations of existing valves and hydrants relative to the repair work will dictate the particular approach to disinfecting that particular section of main.

Whether the old main is opened by accident or design, the excavation is always wet and frequently badly contaminated. Thus the likelihood of serious contamination must always be considered in planning proper disinfection procedures. Because there is always a certain amount of urgency involved in putting an old main back into service, the importance of the service rendered by the main will be a determining factor in establishing the methods of disinfection which are to be followed.

Where sections of old pipe must be replaced or new appurtenances installed, the excavated trench must be kept in a dry condition while installation is underway. Construction precautions should be similar to those employed in the installation of new mains. The interior of each replacement pipe should be swabbed with a strong chlorine solution. Valves, fittings and other appurtenances should be washed with one per cent chlorine solution immediately prior to installation.

Ideally the isolated section of main should be thoroughly flushed and chlorine added to produce a minimum 50 ppm chlorine solution. At least a 10 ppm chlorine residual should be present in the affected section after 24 hours of contact time. Flushing and chlorination through existing hydrants is most convenient but in some cases it may be necessary to install a special flushing tap which may also be used for introducing chlorine. In all cases the chlorine shall be applied in such a way as to ensure that a high concentration reaches every part of the isolated section of

main. Bacteriological testing and resultant acceptance or rejection for service will dictate the need for re-disinfection. Adequate initial chlorination can significantly reduce the chance of inadequate disinfection.

3.2 Minor Leaks and Repairs

Many minor leaks may be successfully repaired through the use of clamping devices and repair sleeves. Often the repairs are carried out while the mains continue to supply water under pressure. The leak or break should be fully exposed and cleaned of dirt and other contaminants before repair. In addition, the gasket which comes in contact with the break should be thoroughly disinfected with a strong chlorine solution immediately before it is clamped to the main. Following completion of repairs the system in the vicinity of the leak should be sampled for bacteriological contaminants. A clean repair job is essential for keeping contamination out of the system.

DISINFECTION FOR SYSTEM PROBLEMS

4.1 Types of Problems

Disinfection of a water system or operating equipment is required when adverse bacteriological tests show the presence of coliform bacteria, the usual indicator of contamination. This may be the result of water system construction or repair activities. On the other hand disinfection may be necessitated to combat colour, taste and odour problems which develop due to the presence of nuisance organisms in the system; such are the iron bacteria and sulphur reducing bacteria. By maintaining a chlorine residual in the distribution system these non-pathogenic slime-forming organisms can be controlled.

The common iron bacteria, Gallionella, Leptothrix and Crenothrix are pipeline growths which derive their energy from the oxidation of ferrous iron. The resultant growth is a mesh of threads encased in a slimy sheath which traps and holds insoluble oxidized iron as well as other organic and inorganic solids. It is interesting to note that

the growth of Gallionella is favoured in cold waters while Leptothrix and Crenothrix thrive in warmer waters. Sudden flow reversals or velocity changes in the mains can disturb settled iron precipitate and break loose varying quantities of iron bacteria for discharge. While "red water" conditions are not necessarily accompanied by the presence of iron bacteria their existence may intensify the colour and taste problems.

In oxygen depleted water, many of the lower bacteria are capable of reducing sulphur to the odourous hydrogen sulphide. One particular species grows best in warm, sulphate-bearing waters and might be found in abundance in dead-end mains and in the bottom of hot water tanks. Where sulphides are formed a black sediment and offensive odours are very evident.

Where colour, taste and odour problems, of the types related to iron and sulphur, are found in a system then samples should be examined under laboratory conditions for the presence of iron and sulphur reducing bacteria. It should be stressed that disinfection is intended to rid the system of these nuisance organisms and not to remove iron from the water supply. The use of disinfection to control these bacteria is governed by the necessity for maintaining a high enough chlorine residual to reach the infected area while, at the same time, not causing serious chlorine taste problems. To be effective, chlorination must be accompanied by an adequate flushing programme.

4.2 Disinfection of Small Chlorinated Systems

Where a water works system is equipped with chlorination facilities at the source, the distribution system or other appurtenances can be disinfected by increasing the chlorine residual leaving this source. The primary residual is raised to, say 0.5 ppm, and hydrant flushing is carried out to obtain some residual in the infected area. The disinfection programme can be carried out for a few weeks or as bacteriological results indicate. Flushing may have to be repeated a number of times to maintain a residual in the infected area. It is noted that even trace residuals over a long period of time will be effective.

In urgent cases, such as where serious coliform contamination is encountered, higher chlorine residuals may be warranted.

4.3 Disinfection of Large Chlorinated Supplies

In large distribution systems it may be difficult to maintain even a trace chlorine residual without having a very high residual at the source, and/or wasting excessive quantities of flushing water. The creation of a chloramine residual is sometimes a solution. The addition of one part ammonia to three parts chlorine will create this residual which will last longer than a free chlorine residual. However, the disinfecting power of this combined residual is greatly reduced over that of a free chlorine residual. Therefore, this change should not be made without careful consideration as to its effect on the bacteriological quality of the treated water.

When first attempting to blanket a large distribution system with a chlorine residual, taste problems may develop. Also, difficulty may be encountered in blanketing the system with even a chloramine residual. At first the oxidation and destruction of organic matter and various infestations will use up the applied higher residual, but after a time the taste problem should stop and the residual advance to the required areas. The end result will of course be a much cleaner distribution system.

4.4 Disinfection of Unchlorinated Supplies

When a water works system is not equipped with permanent chlorination facilities, a temporary method must be devised for injecting the chlorine into the infected parts. Batch addition of a chlorine solution or the installation of a chlorinator will be required. Generally the batch addition of chlorine solution is not to be recommended. Where a storage well is available, such as a spring reservoir, a simple drip arrangement may be devised for obtaining the necessary residual. Again the chlorine residual may be maintained at say 0.5 ppm at the nearest consumer. Frequent flushing may again be needed to maintain the required residual in the infected area.

The disinfection of a distribution system serving an unchlorinated well supply may require the installation of a hypochlorinator or gas chlorinator on a temporary or permanent basis.

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SURFACE WATER SUPPLIES

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SCOPE

Surface water is that portion of water which appears on the surface of the earth. It may occur as fresh water in streams, rivers and lakes or salt water as in James and Hudson bays. However, with the abundant supply of fresh water in Ontario there is little interest at this time in salt water which requires costly desalinization treatment for domestic or most industrial uses. Extensive desalinization research programs are being conducted in other parts of the world where fresh water is not so plentiful.

The object of this presentation will be to review the source, quantity, quality and some associated problems relating to fresh surface water supplies.

SOURCE

Hydrologic Cycle

The principle of the hydrologic cycle was presented in the lecture on ground water supplies. However, brief reference to the cycle will be made here as it applies to surface water supplies.

Atmospheric moisture reaches the earth's surface in the form of precipitation as rain, snow, hail or sleet. Precipitation, percolation, runoff and evaporation are stages in the hydrologic cycle which essentially operates in a closed system - the earth and its surrounding atmosphere. Of the water descending upon the earth, part falls directly upon water surfaces; part flows over the surface of the ground and finds its way into streams, rivers, oceans and other bodies of water; part is immediately returned to the atmosphere by evaporation from water surfaces, land surfaces, and

vegetation; and part percolates into the ground to become ground water.

The water which flows over land surface and into rivers, lakes, etc. is known as runoff. Runoff may be derived directly from precipitation or from ground water seepage.

Snow may evaporate to some extent but in temperate climates most of it remains to melt and run off in the spring, thereby contributing to spring runoff and surface water supplies.

QUANTITY

We have established that the source of our fresh water is due to precipitation. However, only a portion of this water is available to surface water supplies; the major portion being that due to runoff.

There are significant variations in precipitation and runoff throughout Canada because of its many different climatic and geographical regions. Table 1 clearly illustrates these variations.

TABLE 1

Estimates of Annual Precipitation and Runoff for
Settled Areas of Canada (1)

<u>Region</u>	<u>Precipitation (inches)</u>	<u>Runoff</u>		
		<u>Percent of Precipitation</u>	<u>Depth in inches</u>	<u>Ratio to Canadian Average</u>
Canada	28	48	13	1.00
Maritimes	41	62	26	1.95
Quebec	38	39	14	1.10
Ontario	30	37	11	0.85
Prairies	16	17	3	0.21
West Coast	31	78	24	1.85

(1) Cass - Beggs, D., "Water as a Basic Resource", Resources for Tomorrow. Ottawa: Queen's Printer, (1961)

There are more concentrated areas which have precipitation from greater than 60 to only 16 inches per year.

The east and west coasts indicate runoffs of 62 and 78 percent respectively. In the settled areas of the west coast, the geology, steep-sloped terrain, high rainfall, low evaporation, rapid snow-melt, all combine to yield a high degree of runoff.

The precipitation varies from 18 to 20 inches annually along the Ontario - Manitoba boundary to 38 inches at two or three locations in southern Ontario and 40 inches in the area immediately north of Sault Ste. Marie. The average annual precipitation in northern Ontario is approximately 28 inches and in southern Ontario 33 inches. Assuming an average annual precipitation for all of Ontario to be 30 inches, we can estimate the approximate amount of precipitation that falls in Ontario, annually.

The total area of Ontario is 412,582 square miles of which 68,490 square miles, or 17 percent is water. If we use 30 inches as the average annual precipitation, approximately 180,000 billion gallons of fresh water fall on the province annually. This amounts to roughly 1.2 million gallons of water per day per square mile.

A large proportion of this water is not available to man since some is returned to the atmosphere by evaporation from land and water surfaces and by transpiration from vegetation. Here again this amount varies with the location and is dependent upon such factors as temperature, nature of soil, vegetation, rate and frequency of precipitation, etc. We should be aware that although all of the precipitation cannot be used directly by man, some of it is serving a very useful purpose by supplying water to our gardens, lawns, crops and forests.

If we assume that approximately 60 percent of the total precipitation is that amount of water which is directly lost to man due to evapo-transpiration in Ontario we obtain a figure of 72,000 billion gallons. This amounts to 0.5 million gallons per day per square mile which theoretically would be available for our domestic, agricultural and industrial uses.

In addition to having our surface water resources renewed by nature at reasonably regular intervals by precipitation,

vast quantities of water are held in storage in the lakes and additional quantities are moving through the ground to discharge to surface bodies of water. In a bustling metropolis the range of water consumption is generally 100 to 150 gallons per capita per day. This relatively high usage reflects the industrial water demand as well. In rural areas where homes may not be equipped with a pressure system the normal demand is about 10 gallons per capita per day. In a residential village the average daily range of water consumption is 40 to 60 gallons per capita.

Ontario has a population of approximately 7 million persons. A quick mental arithmetic calculation based on the above data will reveal the approximate water demand in this province. This figure should be compared to the amount available in order to realize the abundance of surplus water.

Records

Various hydrological records are compiled and maintained by the different agencies of the federal and provincial governments. A listing of some of these agencies is given below and pertinent information may be obtained by contacting the relevant branch.

Precipitation Records	- Meteorological Branch Department of Transport
Streamflow Data	- Inland Waters Branch Department of Energy Mines and Resources
Water Quality Records of Major Lakes and Rivers in the Province of Ontario	- Water Quality Surveys Branch Ontario Water Resources Commission
Well Records, Provincial Streamflow Data, Records on Groundwater Tables	- Division of Water Resources Ontario Water Resources Commission
Water Levels of the Great Lakes and Other Navigable Waterways	- Canadian Hydrographic Service Department of Energy Mines and Resources

The latter records may be a useful guide when undertaking intake location studies.

QUALITY

Another glance at the hydrologic cycle will indicate that the sources of surface water are direct precipitation, surface runoff and groundwater seepage or springs. A closer study of these sources reveals that the water is subjected to a number of factors which will influence the chemical, physical and biological quality of the water supply. In addition, a surface supply is always susceptible to polluting wastes discharged by industrial, municipal, agricultural, private domestic and other similar sources. This will also affect the quality of the water supply.

Precipitation

Water vapour condensed as clouds or precipitation present in the atmosphere is relatively free of any undesirable particles. However, as the precipitation approaches the earth's surface it absorbs oxygen, carbon dioxide and other gases from the air. It may also be affected by smoke, dust and various types of bacteria in its descent. It is, therefore, evident that rain or snow falling on rural areas is freer from these particles than that falling on cities.

Rain water tends to be soft and saturated with oxygen but flat to the taste and somewhat corrosive.

Ground Water

It was described earlier that some of the water falling upon the surface of the earth percolates into the ground to become ground water. A more intensive discussion on ground water (than will be attempted here) is presented in another lecture. However, you should be aware that in some cases ground water may again reappear on the earth's surface as ground water seepage or springs; thereby affecting the quality of the surface supply to which it may be contributing.

The relatively slow movement of water percolating through the ground affords intimate and lengthy contact of the water with the minerals constituting the earth's crust. These minerals are soluble to some degree so that the water tends to increase in mineral content in its movement until some form of

stability is reached. The eventual chemical constituents present in the water is naturally dependent on the environment to which it has been subjected.

Most ground water contains no suspended matter and practically no bacteria. Hence it is usually clear and colourless and of superior sanitary quality than surface water.

In limestone formations ground waters tend to be hard, scale-forming in pipes and relatively non-corrosive. In granite regions the ground water is soft, low in dissolved minerals, relatively high in free carbon dioxide and actively corrosive.

An important element in its consideration as a supply or as a significant factor of its influence on surface supplies is its relatively constant temperature throughout the year. A general guide of its expected temperature is ground water 10 to 50 feet below the surface is usually the mean atmospheric temperature of the locality. Below 50 feet the temperature increases roughly by 1°F. for each 60 feet in depth.

The ground water may reappear on the surface in the form of a spring. This occurs when the ground water table intersects the surface of the ground. Sometimes springs issue from rock fissures. In general the quality of water from a spring reflects the geologic formations of the locality in which they occur. Ordinarily, the availability of water from springs is limited and not dependable for supplying to a large community. Consequently its use is often restricted to low-demand water areas or as a supplement to another supply.

Surface Runoff

As precipitation or ground water finds its way to its ultimate surface destination, its quality may undergo significant changes. As the water flows over the surface to a common collection stream, river or lake it may flow through wooded areas, swamps, agricultural fields and populated communities.

A quick look at the water quality or the influential

factors affecting it will be reviewed as it flows through these various environments.

Wooded Areas

A sample of water flowing through a wooded area or forest may impart a faint vegetable odour due to the presence of a small amount of organic matter of plant origin. It may also exhibit a faint but noticeable colour.

The water may be well oxygenated but low in carbon dioxide content. The water is generally in the neutral pH (7.0) range and contains little iron.

Nutrients such as nitrates and phosphates are not commonly present in large enough concentrations to stimulate the growth of microscopic organisms.

Agricultural Areas

Drainage from agricultural areas may contain mineral and organic matter. All forms of nitrogen are generally present along with colour and turbidity. The water may lose some of its oxygen content as a result of draining through this fertile area.

Furthermore, surface runoff from agricultural fields introduces nutrients in the form of nitrogen and phosphorus to lakes and rivers. This tends to stimulate and promote a prolific algae growth in the body of water. This particular aspect of uncontrolled nutrient discharge to our waterways is a major concern to the OWRC. This Commission has initiated research programs of this nature in conjunction with other interested branches of the government to seek methods of averting the problem. Research publications have been issued indicating the problem and presenting recommended agricultural techniques which farmers should employ to curtail nutrient discharge to watercourses.

Populated Communities

The runoff water may accumulate in a stream and ultimately flow through a developed community. Hopefully there are no sources of untreated domestic and industrial wastes entering the watercourse; however, this is often not the case.

The chemical and physical condition of the water is dependent upon the nature and capacity of the pollution load entering the stream. The water works operator should be aware of the type of wastes that are or may be discharged to the stream so that effective treatment could be afforded at the plant at all times. Representatives from industries should keep the water works personnel informed of any accidental or abnormal industrial waste spillages occurring upstream of the water treatment plant intake. This is to prepare the operators in making any adjustment in the treatment process so that a water of the desired quality is maintained in the distribution system.

The biological, chemical and physical characteristics of the water in the stream described above depends on the quality and quantity of the municipal waste discharge. A body of water whether it be a lake, river or stream is a natural habitat for a great number of minute organisms such as bacteria and algae. Particular species of micro-organisms are harmful to man (pathogenic) and must be removed or destroyed prior to human consumption. It is difficult to control what may be discharged into a surface water supply; therefore, this water should be adequately chlorinated prior to delivery to the distribution system. Specific instructions for chlorination procedures have been set out in a bulletin by the Ontario Water Resources Commission and is available upon request.

INTAKE STRUCTURES

The intake refers to that portion of a surface water supply system that conveys the water from the source to the raw water pumping station or water purification plant.

The intake is an expensive item and cannot be readily altered, enlarged or relocated once it has been constructed. Therefore, careful planning with respect to location, capacity and construction is needed. The location of these works is determined by existing facilities, economics and physical conditions. Capacity is normally provided well beyond immediate needs and in relation to projected growth. The geological conditions of the site must be examined and related to the stability of the works and construction methods.

The intake is often situated well below the surface of

a lake or river where the water temperature is more constant and favourable than at the surface.

The water works intake should be placed in water of such depth that bottom sediments are not stirred up by wave action and that ice problems are minimized. It should be located upstream of any storm or sanitary sewer outlets and well away from bathing areas. It should also be kept as distant as possible from marine traffic areas. The boating public should be made aware of the locations of the intakes.

The following records taken for a period of at least a year would be valuable in assessing an area for the location of an intake structure:

- (1) High and low levels and flows
- (2) Water quality such as hardness, turbidity and colour
- (3) Average, maximum and minimum water temperatures in the zone where the intake is proposed to be placed
- (4) Location of tidal salt water intrusions
- (5) Water current patterns

PIPELINES

Some inland municipalities are experiencing water shortages to supply their domestic and industrial demands. To alleviate the problem the OWRC has entered into direct agreement with some of these municipalities on an individual or area basis to arrange, on their behalf, financing and construction of works that will provide them with water. The water is collected from surface sources where the supply is abundant, afforded complete treatment and pumped to the municipality. One such pipeline in existence extends for a distance of 30 miles and serves municipalities at intermediate and terminal points.

CONCLUSION

The source and abundance of surface water in the Province

of Ontario has been reviewed. Water is necessary to a region if it is to continue to progress. With the rapid development in Ontario conservation practices will play an important role in resources management and development.

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BASIC ELECTRICITY

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BASIC ELECTRICITY

The word electricity is derived from the word electrum, which in Latin means amber, because the first electrical discovery was made in connection with amber. Amber and lodestone both have strong attracting qualities. Electricity is an invisible force of nature which may be controlled under certain well known laws. An electrical law is a fact or set of facts which have been proven by experiment.

THREE ELECTROSTATIC LAWS

1. When two unlike unelectrified bodies are rubbed together, one will take on a positive charge and the other, a negative charge.
2. When an unelectrified body comes in contact with an electrified body, it will take a charge similar to the electrified body (electro static induction).
3. Like charged bodies repel and unlike bodies attract each other. As most of us have had some experience with small permanent magnets, we know that like poles repel and unlike poles attract.

THE ELECTRON THEORY

All materials are composed of atoms. An atom is a part of matter which may be divided into by electrical means. It is invisible. An electron is many times smaller than an atom. The atom consists of a positive centre or nucleus which comprises neutrons and protons and revolving around this nucleus are tiny negative electrons. The normal atom has an even balance of positive and negative charges.

STATIC ELECTRICITY

Static electricity is electricity at rest in the form of charges. It may be produced by means of friction or induction. It is of very little commercial value, because it cannot be used for light, heat or power. It is used for experimental purposes and for testing insulating materials. A typical example of static electricity, which I am sure you have all come in contact with it when you cross a floor with a heavy carpet on it and you touch something metallic on the other side such as a doorknob, etc., you will get a slight tingle in your fingers.

MAGNETISM

Magnetism is an invisible force of nature which seems to have always existed. The invisible force which exists between the poles of a magnetic is known as the magnetic flux, or lines of force. It is assumed to be always in motion, always in rotation. Lines of force lead at the North Pole of a magnetic and enter at the South Pole. First law of magnetism - like magnetic poles repel and unlike poles attract each other. Second law of magnetism - the force exerted between two poles of opposing magnets is inversely proportional to the square on the distance between them. Magnetism affects only magnetic metals, iron, steel, nickel, cobalt, etc. Nickel and cobalt are only fair attractions.

Natural & Artificial Magnet

Natures magnet is lodestone. Artificial magnets are magnets made by induction, temporary, permanent, and electro-magnet.

The Molecule Theory of Magnetism

The little molecules which make up magnetic metal are tiny magnets, which line up with their North Pole all in one direction when the metal is magnetized. A temporary magnet is made of soft iron and has the qualities known as permeability. Permeability is a measure of ease with which magnetism passes through a substance; a permanent magnet is made of hard steel and has a quality known as retentativity.

The Molecule Theory of Magnetism (continued).....

Retentativity is the ability to hold the molecules lined up.
Reluctance is the opposition offered to magnetism.

Electro Magnets

An electro magnet is a coil of insulated wire wound on a soft iron core. The magnetism is produced by means of a current passing through the coil of wire.

Electro Magnetic Induction: when a conductor or wire is moved through a magnetic field an electrical pressure will be induced into it. The voltage induced into the armature of a generator will depend on three things.

1. The number of turns in series.
2. The strength of the magnetic field.
3. The speed of the turning R.P.M.'s of the armature, will give the direction of the current flow.

When given the direction of the current, to find the direction of the whirls, place the thumb pointing the way the current is flowing and the fingers will give you the direction of the whirls. It is important to note that only the right hand is used.

ELECTRO MAGNETIC INDUCTION

Transformers

A transformer is a device used to increase or decrease A.C. Voltage. It consists of two separate windings on a laminated iron core. One winding is known as the high tension winding and low voltage. The high tension voltage winding has a greater number of turns and smaller wire. The primary side of the transformer is always connected to the source, the secondary side of the transformer is always connected to the load.

ELECTRO MAGNETIC INDUCTIONTransformers (continued).....

When the transformer is to be used for a step-up transformer, the low tension winding is used on the primary. On a step-down transformer the high tension winding is used on the primary. Transformers are 99.6% efficient in high voltage but they are only about 86% in lower voltages.

There is no electrical connection between the primary and secondary windings. Voltage induced in the secondary winding of a transformer depends upon the ratio of the number of turns to the number of turns on the primary winding, and the pressure applied to the primary voltage. Assuming transformer is 1000 V at 100% efficiency and 2 amps are applied, 10:1 step down, watts in the secondary step-down - 100 volts x 20 amps equals 2000 watts.

CONDENSER

A condenser is a device used to store electrical energy. It consists of two conductors, the plates which are separated from each other by insulating material known as di-electrics. The charges in a condenser are stored on the surface of the di-electrics. A fixed condenser has a fixed capacity. Electrons move from a negative charge to a positive charge. Examples of static electricity are: lightning, around printing machines, etc. Method of moving static from such moving objects - the frame is grounded to earth. Another example of static electricity charge going to earth is on many a big fuel truck from which you will see a chain dragging which diverts any static electrical charge to earth.

DYNAMIC ELECTRICITY

Dynamic electricity is electricity in motion or current; current is necessary to operate electrical equipment. It differs from static charges in three ways:

1. Its potential is lower.
2. Its actual quality is much greater.
3. It is continuous.

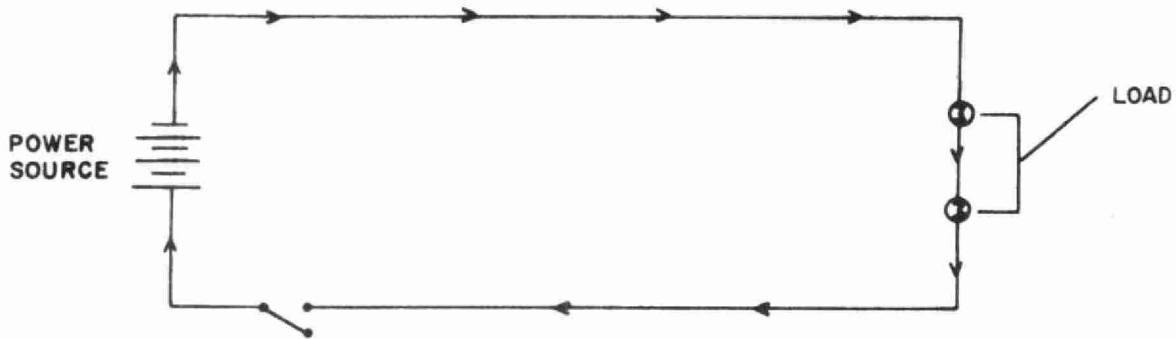
Three methods of producing dynamic electricity are:

1. Thermally by means of heat as by the thermo-couple in a pyrometer. When two unlike metals are joined together and heat is applied to the joint, an electrical pressure will be generated, which will cause current to flow when the circuit is completed.
2. Chemically by means of cells and batteries. When two unlike elements are immersed in a chemical solution (electrolite) a chemical action takes place which generates an electrical pressure and causes current to flow when this circuit is completed.
3. Mechanically by means of generators and magnets. When a coil of wire is moved through a magnetic field an electrical pressure will be induced into the coil, which will cause current to flow when the circuit is completed.

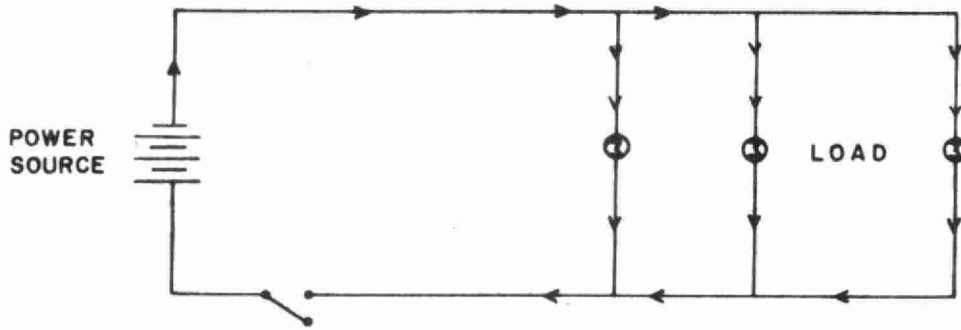
There are four effects produced by current:

1. Heating effects such as lamps, toasters, irons, etc.
2. Chemical effects such as in battery charging, electroplating and electrolysis. (the chemical decomposition of water or other substances by electricity).
3. Magnetic effect as in motors, buzzers, relays, annunciators, etc.
4. Physiological effect, the effect of current upon man and beast.

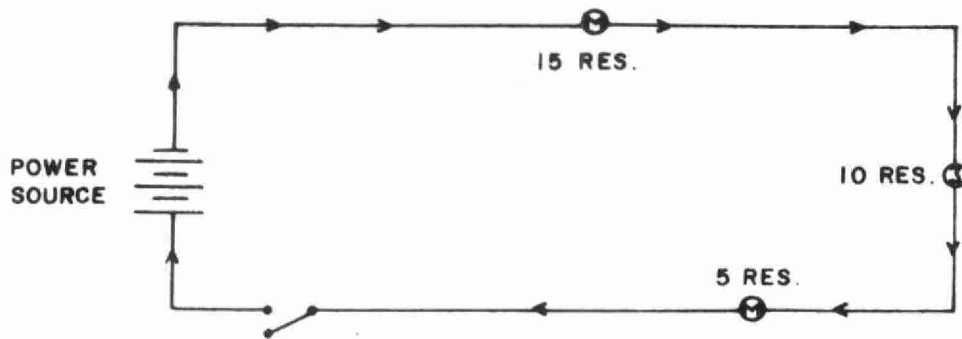
SERIES CIRCUIT



PARALLEL CIRCUIT

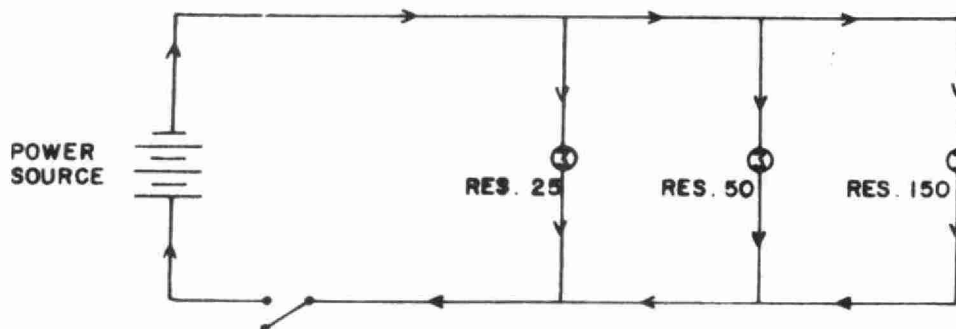


SERIES CIRCUIT



TOTAL RES.
 $15 + 10 + 5 = 30 \text{ OHMS RES.}$

PARALLEL CIRCUIT



$\frac{1}{25} + \frac{1}{50} + \frac{1}{150} \text{ RES.}$

$\frac{6 + 3 + 1}{150} = \frac{10}{150}$

RECIPROCAL $\frac{10}{150} = \frac{150}{10} = 15 \text{ OHMS}$

MOVEMENT OF DYNAMIC ELECTRICITY

Movement can be compared or illustrated by using as an example, a waterpiping system. Pressure on piping in a system either by elevated tank or pump compares with voltage or potential in electrical terms. It is actually the driving force. The rate of flow of water through piping compares with amperes in electrical terms, and the friction of piping which retards water flow compares with the resistance or ohms in electrical terms. So, in water and electricity, we have somewhat a similar action when they are in motion.

WATTS-OHMS LAW

These laws are very important. They are used to calculate the four fundamentals of electricity—pressure or volts—current or amps — resistance or ohms and power. They should be memorized letter perfect. Every electrical circuit consists of three factors: volts—resistance—current. Ohms Law teaches the exact relation between the three factors.

SERIES AND PARALLEL (See Figures 1,2,3 & 4)

A simple and practical electrical circuit consists of a source of energy, a load, and a means of control. A series circuit is where the current has only one path from the source all the way around and back to the same source. Current will follow the same rate through each device in a series circuit. Naturally, the voltage across each device will have to be added. A parallel circuit is where the current has two or more paths. Current in any path depends on the resistance in that path.

ELECTRICAL CONDUCTIVITY

As we know the atom is comprised of electrons and protons. Electrons have a negative charge and protons have a positive charge. In conductors, electrons move freely. Conductors are used in controlling and harnessing electricity in a given path or flow. Insulators, as you know, restrict the flow of electrons and this method of insulation protects against contact with live parts of the conductor and the better the insulation the higher the resistance against it. Thus, by means of conductors and insulators or insulation we can safely supply electricity to the systems and controls through switches and controllers, etc.

SAFETY SWITCHES - BREAKERS AND CONTROLS

On all our electrical equipment we have controls and electrical protective devices used to safely control their operation. Fusing on electrical switches and current limitations on electrical breakers are the first line of protection for the equipment; their uses are simply to protect from any overcurrent above the equipment rating, that may damage same. So, do not put a higher rated fusing than the rating of the conductor or equipment can safely carry. When you do overfuse the known rating of equipment, you are making it prone to damage, through high current which may occur in your electrical system.

There are many fuses to choose from and they have different time limits for blowing. Some fuses are of the re-newable type; others are called one-time. All fuses should be pulled and installed with a proper fuse puller.

Circuit Breaker

A circuit breaker may be described as a device for making and breaking a circuit under normal and abnormal conditions. As with fuses, the continuous current rating of a circuit breaker is determined by the rating of its trip element, which is the value at which the circuit breaker will trip automatically on overload or short circuit currents.

MAINTENANCE OF MOTOR MAGNETIC STARTERS (Continued).....

A check list should be drawn up of the various points to check on an average motor contactor or control, as follows:-

1. Remove any dust or dirt by blowing or vacuuming.
2. Check for overheating or loose connections.
3. Check for friction or binding of moving parts.
4. Check contacts for wear and contact pressure.
5. Check control voltage to solenoid coil.
6. Check ARC chutes (if any) for wear or breakage.
7. Check flexible shunts for burning or breakage.
8. Check auxiliary devices such as push button stations etc., and clean where necessary.
9. Test operate the starter on control.

In general, good maintenance of motor starting equipment requires a good systematic program of steady inspection. With properly designed equipment, the frequency of inspection will depend on the normal wear and tear on the equipment. Experience will soon indicate the equipment subjected to severe service, and which will of course, require more frequent inspection.

All maintenance personnel should be thoroughly trained and supplied with up to date wiring and schematic diagrams, also operation and sequence manuals. The maintenance man should be trained to make fast, thorough inspections and safe temporary repairs if it is going to take too long to make permanent repairs. Permanent repairs can be made at a more opportune time when the equipment can be spared from service.

Reports of troubles must be made out, and complete records kept of all maintenance and inspection.

An adequate supply of renewable parts should be available, such as solenoid coils, spare contacts, etc. Parts that frequently require renewal, are generally inexpensive and easy to obtain from the manufacturer of the equipment.

ON FIRST AID

All personnel shall have some training in first aid. The knowledge of knowing how to employ artificial respiration is a must. For if a victim received a severe electrical shock he is sometimes knocked unconscious and it is of the utmost importance to use this method to revive him.

If the victim cannot let go of the electrical conductor, throw the disconnect switch. If this is not possible use something like a dry stick to push him away from the electrical conductor. Once again, I stress the use of electrical safety gloves on the site and once again please be careful. We like to see you around.

MOTOR CONTROL CENTRES

If we inspect a typical Motor Control Centre in our plants, we note that the control centre is composed of a number of different motor control panels. Each panel is fitted with its own motor control components which are usually as follows:-

1. Moulded-Case Circuit Breaker
2. Motor Magnetic Contactor
3. Control Transformer
4. Control Fuse
5. Terminal Strip

Each of these individual motor control panels is designed to "Plug-In" to 3 vertical bus bars in the rear of the control centre to provide a three phase-550 Volt-60 cycle alternating current to energize the electric motor which is connected to that particular control panel.

If we trace the wiring inside the control panel, we note that the "Plug-In" three phase electrical supply is connected to the top or "LINE" side of the Moulded-Case Circuit Breaker. When the breaker is switched "ON" the 3 phase supply is fed from the "LOAD" side of the circuit breaker into the top or LINE side of the Motor Magnetic Contactor to 3 heavy stationary contacts. A two phase supply is also connected to the PRIMARY winding of the control transformer where the 550 volt supply is reduced to a safer control voltage of 120 Volt.

In turn, the 120 Volt Control Voltage is supplied through a small control fuse to Push-Button-On/Off stations, from whence it is forwarded when required, to energize a solenoid coil inside the Motor-Magnetic-Contactor. When the solenoid coil is energized, it exerts a magnetic pull on the moving or LOAD portion of the magnetic contactor and closes same.

As the magnetic contactor closes, the three heavy contacts which are connected to the 3 phase supply, make contact with 3 matching contacts on the moving portion of the contactor which has been pulled in by the solenoid coil's magnetic influence.

MOTOR CONTROL CENTRES (continued).....

The 3 phase 550 Volt Supply Voltage is now fed from the LINE side of the contactor to 3 terminals on the terminal strip, usually marked, T1, T2, T3.

From these 3 terminals, 3 motor cables are connected to the motor stator windings, so that now, a 3 phase 550 Volt 60 Cycle, A. C. electrical supply is connected directly to the motor windings to energize and turn the motor.

In the full operation of the motor control circuit as was just described, it would be necessary to continue pressing the "ON" button in order to energize the motor contactor solenoid coil. This is, of course, out of the question, so therefore the motor contactor is fitted with auxiliary contacts to make a retaining circuit once the contactor is closed so that the solenoid is now supplied with electricity from another source and the press button can then be released.

When a "STOP" button is pressed, the control voltage to the solenoid is interrupted and the magnetic contactor opens to disconnect the 3 phase 550 volt supply from the motor windings to stop the motor. The contactor will remain "OF" until the "ON" button is again pressed.

MAINTENANCE OF MOTOR MAGNETIC STARTERS

Modern Motor Magnetic Starters have been designed to operate successfully for millions of successful operations, but like other types of moving equipment, are subject to wear and eventual failure or breakdown.

The maintenance man must anticipate such ultimate failure, and make the all important repairs or replacements ahead of the estimated time of failure.

There are certain things that must be inspected weekly, others monthly, and yet others quarterly or every six months.

OPERATION OF AUXILLIARY STAND-BY

POWER EQUIPMENT

DIESEL AND GASOLINE ENGINES

A. Davies
Technical Specialist

The following deals with the basic principles which are applicable to all engines. However, engines of different types and makes differ greatly in details. Therefore, for specific instructions regarding a particular make of engine one should always refer to the engine builder's manual.

Both diesel and gasoline engines are internal combustion engines. An internal combustion engine is classified as a heat engine whereby its power is produced by burning fuel. The power stored in the fuel is released when it is burned. The word internal means that the fuel is burned inside the engine itself. The most common fuel used are diesel oil for diesel engines and gasoline for gasoline engines. An ample supply of oxygen is required for proper combustion.

BASIC ENGINE PARTS

The most essential of these parts that make up both diesel and gasoline engines are: the cylinder, cylinder head, piston rings, connecting rod, crankshaft, flywheel, valves, camshaft and crankcase.

Cylinder

The cylinder is made of cast-iron. It is round and has a finely machined surface in which the piston slides up and down.

Cylinder Head

The cylinder head is made of cast iron, and is bolted tightly to the top of the cylinder. It also forms the top of the combustion chamber. It contains the fuel injector for a diesel engine and a spark plug for the gasoline engine.

Piston

The piston, commonly made of aluminum, slides up and down in the cylinder. The duties of the piston are to compress the air charge and to receive the pressure of the burning and expanding gasses.

Piston Rings

The piston rings provide a tight seal between the piston and the cylinder wall. Without the piston rings the expanding gasses would escape into the crankcase. The piston rings also reduces friction and control lubrication of the cylinder wall.

Connecting Rod

The connecting rod, made of steel, connects the piston and the crankshaft. It is the duty of the connecting rod to transmit force in either direction between the piston and the crank on the crankshaft.

Crankshaft

The crankshaft, made of steel, converts the reciprocating motion of the piston into rotary motion.

Flywheel

This is a very heavy wheel made of cast iron. It is fastened firmly to the crankshaft and its purpose is to smooth out the operation of the engine. When the force of combustion pushes the piston down, the momentum of the flywheel helps to move the piston back up the cylinder. This eliminates the intermittent jolts of power during combustion.

Valves

The valves are used to admit air and discharge the exhaust gasses from the cylinder.

Camshaft

The camshaft is driven by the crankshaft and controls the opening and closing of the inlet and exhaust valves. On diesel engines it operates the fuel pump.

Crankcase

The crankcase made of cast iron, houses the crankshaft and has bearing surfaces on which the crankshaft revolves.

The lubricating oil pump and reservoir of oil are located in the crankcase.

Both types of engines are provided with starting motors to crank the engines.

CYCLES OF OPERATION

Diesel and gasoline engines operate on either the two-stroke or four-stroke cycle of events in each cylinder. This means that it requires either two strokes or four strokes of the piston to:

1. draw in a charge of air
2. compress it to a high pressure and temperature
3. burn the fuel and allow the gasses to expand
4. deliver their power to the crankshaft and blow out the exhaust gasses so that the cylinder is ready for the next cycle.

One revolution of the crankshaft completes a cycle in a two-stroke cycle engine. Two revolutions of the crankshaft completes a cycle in a four-stroke cycle engine.

The most common method of engine operation is the four-stroke cycle. It is an efficient and successful producer of power. Its operation is explained in detail below:

HOW DIESEL AND GASOLINE ENGINES WORK

The main difference between a diesel and a gasoline engine lies in the "ignition system". In a diesel engine the high temperature of the compressed air produces the ignition. In a gasoline engine, a spark produced by a magneto or battery-coil ignites the fuel.

OPERATION OF THE FOUR-STROKE CYCLE

1. Suction

In the gasoline engine, fuel and air mixture are drawn into the cylinder during the first or induction (suction) stroke. In the diesel engine, however, only filtered air is drawn into the cylinder.

2. Compression

During the second stroke of the gasoline engine, the fuel and air mixture is compressed to a suitable pressure prior to ignition.

In the case of the diesel, the air is compressed to a much higher degree and, therefore, becomes extremely hot.

3. Expansion

During the third stroke of the gasoline engine, the compressed fuel and air mixture has been ignited by an electrical spark from the spark plug.

In the diesel engine, raw fuel is injected at high pressure in the form of an atomized spray into the already hot compressed air in the engine cylinder. This causes the fuel to ignite and the resultant expansion in the cylinder gives us the power stroke.

4. Exhaust

During the fourth and last stroke of both the gasoline and diesel engines, the burnt gasses are expelled from the cylinder prior to the next stroke and new cycle.

OPERATING POINTERS

For efficient operation, both diesel and gasoline engines require:

1. Air - An abundant supply of air for proper combustion which must be filtered to prevent internal engine surface from being damaged by abrasive material the air might carry.
2. Fuel - Good quality, clean fuel with the best filtering system between supply tank and engine. A constant supply must be maintained.
3. Lubrication - High grade quality of lubricating oil and a reliable pump driven off the engine to deliver oil continuously at pressures ranging from 30 to 75 p. s. i. g. (depending on manufacturer recommendation) to hundreds of moving parts.

A filtering system to remove sludge and dirt.

4. Cooling

An efficient cooling system to maintain a working temperature of no less than 165°F and not higher than 180°F on jacket water and not over 150°F on lubricating oil.

5. Speed Control - To maintain a definite speed or a specific speed range without speed fluctuations a governor is required to control fuel in accordance with engine load.

6. Ignition Systems:

Gasoline Engine

In a gasoline engine the carburetor must prepare a mixture of gasoline and air in the correct proportion for burning in the combustion chamber.

A magneto or battery-coil system provides the spark to the spark plug for the ignition.

Diesel Engine

In a diesel engine, the fuel pump meters and forces fuel under very high pressure into the injector where it is discharged in an atomized form into the cylinder.

The heat of the compressed air in the cylinder ignites the fuel.

7. Starting System

The starting battery is the most important part of the system and should never be ignored. It should always be kept fully charged.

Many plants are equipped with very efficient two rate battery chargers which should be used in order to keep the battery fully charged without damage from overcharge. Keep battery filled with distilled water and test frequently.

TEST STARTING AND RUNNING ENGINES

Every auxiliary stand by unit should be test started and run for a period of two hours at least once a week. This running period in addition to bringing engine to running temperature will eliminate rapid carbonization, drive out condensation and maintain a film of lubrication - so necessary on all bearing surface.

PERFORMANCE RECORDS

Complete records of engine performance should be kept. Whenever the engine operates, record the following:

Cooling water temperature, Lube oil pressure and temperature, Exhaust temperature, if equipped, Electrical or other load data, R. P. M. and total running hours.

It is in these records that the watchful operator spots small troubles when they can be cured inexpensively. A comparatively minor engine trouble, if not recognized and remedied in its early stages, may easily develop into a major breakdown.

